COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May, 1944

Spreader stokers firing three 500-hp boilers for large housing project

Midwest Power Conference ▶

The Combustion Gas Turbine ▶

Addition to Capacity and Modernization of the MARYSVILLE POWER HOUSE—V ▶

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME FIFTEEN NUMBER ELEVEN

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FOR MAY 1944

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

A Tribute to Utility Cooperation

To those who have been regular attendants at the yearly Midwest Power Conferences, the remarks this year of J. A. Krug, until recently Director of War Utilities, WPB, appeared in marked contrast to the views expressed two years ago by Leland Olds, Chairman of the Federal Power Commission. The latter, it will be recalled, was skeptical as to the adequacy of power supply and took issue with the figures offered by the utilities as to their ability to meet war loads. That Mr. Olds' misgivings were not substantiated by subsequent events, despite a volume of war production greatly in excess of that predicted, is now a matter of history. Mr. Krug told what had been accomplished in the intervening two years in meeting power demands through close cooperation between his office and the utilities, and between utilities themselves, and complimented the latter on their resourcefulness in meeting difficult situations. His remarks may be regarded as a tribute to the utilities and reflect credit on the organization he had built up largely from among their personnel.

Evaluating the Gas Turbine

The sudden popular interest in the gas turbine may be attributed to a spreading knowledge that several well-known firms are now engaged in development work along this line, some at the instance of the Government, and to the fact that metallurgical development gives promise of possibilities in the employment of temperatures at which the gas turbine can function effectively. The article by Messrs. Fischer and Meyer in this issue reviews the thermodynamics of the gas cycle in comparison with that of steam and offers predictions as to possible applications as well as limitations of the gas turbine.

From this it will be apparent that the simple gas turbine leaves much to be desired as to efficiency unless such high temperatures be employed as will likely be attended by short life. On the other hand, if temperatures be employed within the range of present available materials to insure long life, high efficiency demands a more complex unit with efficient air compressor, intercoolers, reheaters and heat exchangers. Moreover, present designs are limited in capacity and to the use of liquid fuel.

Despite the talent and research facilities that are now behind development of the gas turbine, one would indeed be over optimistic to conclude that it will be perfected commercially in the near future. It is necessary only to look back on the millions of dollars spent and the number of years required to bring the steam turbine to its present high state of development. Such installations of the gas turbine as have been made thus far in this country have been limited to simple, comparatively low-temperature units operated in conjunction with refinery process and not as a primary source of power.

While the gas turbine in its present state of development cannot be regarded as threatening to supersede existing forms of power generation, especially large and efficient steam plants, it is possible that in time it may prove a competitor to steam in smaller plants, under perhaps 5000 kw, and it also seems to offer some promise in the locomotive field. For obvious reasons, little can be said at the present time as to its potentialities for small or moderate powers in the marine field or in aviation, although experience with aircraft superchargers has provided considerable background for development in the latter field.

As in the case of all new developments, accurate evaluations cannot be made until they have been reduced to practice and indiscriminate predictions must be discounted. Ultimate accomplishments will be measured by the prosecution of research now being initiated, tempered by experience with such installations as are made from time to time.

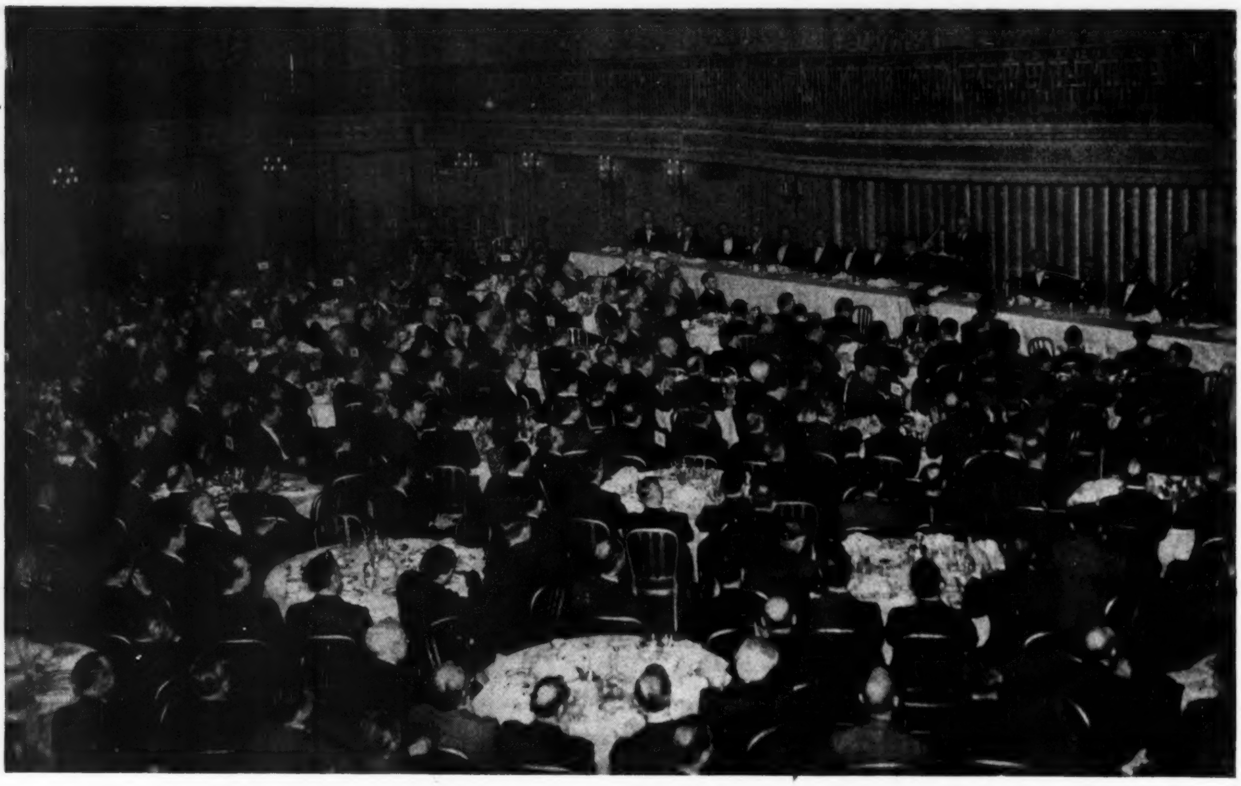
Salvaging Equipment for Technical Schools

One of our contemporaries recently made the suggestion that the Government, in planning for the ultimate disposition of war plant equipment to which it holds title, not overlook the needs of our universities and technical schools. Offhand, this appears to be an excellent idea, inasmuch as some of our technical schools have long been more or less handicapped in the practical teaching of engineering students by the necessity of employing inadequate or obsolete equipment. While this is not true of all schools, it is likely that even the best equipped would welcome some additions, as the present finances of most schools preclude substantial appropriations for equipment.

It will be apparent that some of the machines now functioning in war plants are too special to serve the needs of such schools, but there are undoubtedly many others that would be well suited to instruction purposes, for the war has brought marked progress in the machine-tool field.

As regards power plant equipment, however, it is likely that most of this would prove too large for routine laboratory test work, such as is included in the usual curriculum. At least, this would hold for boilers and prime movers, although certain auxiliaries and some electrical equipment might be put to such use.

It is probable that some steps have already been taken toward this end and that school authorities are alive to the possibilities, such as they may be.



Between five and six hundred attended the "All Engineers" dinner

Midwest Power Conference

FOR the seventh successive year the Midwest Power Conference, as sponsored by Illinois Institute of Technology with the cooperation of eight leading midwestern colleges and local sections of the engineering societies, was held at Chicago April 13 and 14. The estimated attendance was around 2500 with several of the sessions reaching a thousand.

At the opening session, under the chairmanship of **H. B. Dirks,** an address of welcome was given by **Robert B. Harper,** Vice President of the Peoples Gas Light and Coke Company, and response on behalf of the cooperating institutions was made by **Dean F. M. Dawson** of Iowa State University. The latter noted that directives for Selective Service class engineers as specialists rather than as belonging to a profession and that many engineering groups within the Army are not officered by engineers.

Post-War Utility Outlook

The first paper at this session was given by **A. D. Bailey** of the Commonwealth Edison Company, dealing with "Post-War Planning of the Nation's Power Supply." Citing the cooperation of utilities with government agencies during the present emergency, the speaker showed how all essential demands for power have been met to the end that over 40 per cent of the output of all utilities is now being employed in war production. While in 1939 industry was purchasing 60 per cent of its power from central stations, this figure has now increased to 70 per cent. Even in the largest industrial areas the limit of manpower was reached before the limit in electric power.

At the beginning of the war electric utilities were in a fortunate position, for in anticipation of increasing loads they had increased their reserves in generating capacity; in some cases these were increased up to 30 per cent. Moreover, the adoption of "War Time" reduced the total peak by an amount variously estimated at 800,000 to 1,500,000 kw. In the Chicago area alone this difference in time accounted for at least 80,000 kw in the winter peak.

Although plans for the future are difficult because of the many unknown factors, Mr. Bailey cited some statistics indicative of the probable post-war trend.

In the twenty years from 1919 to 1939, the horsepower per worker in factories had practically doubled, and the present war has given a tremendous impetus to increase of power and output per individual. The index of industrial production rose from 130 to 250 in the period from July 1940 to the present, whereas the number of workers increased from 28.6 to 32.7 million, according to the Bureau of Labor Statistics—all this despite the fact that the cream of our productive manhood has gone into the armed services. Recalling that a boom period followed an increase in national income from 57 billion dollars in 1918 to 68 billion dollars in 1920, it was pointed out that national income in 1943 rose to 143 billion dollars of which 85 billion was for war expenditures.

The speaker referred to present pent-up savings, estimated at 36 billion dollars, a large part of which

represents potential buying power for commodities whose production is temporarily suspended; also to new uses for electricity which were just being developed at the start of the war. He showed charts of estimates made by four separate utilities and one covering the country as a whole, regarding the probable trend of electric power sales in early post-war years. While all predicted some drop in output during the conversion period, the most optimistic estimate predicted an output greater than that of 1943 in the third post-war year; another anticipated a drop of 18 per cent below the 1943 figure with relatively slow recovery; and the most pessimistic estimate, dealing with the country as a whole, predicted a drop of 22 per cent below 1943 in the first year, a further drop of 6 per cent by the end of the third year and then a steady recovery. The average of the four estimates shows a drop of 13 per cent in the first post-war years, with a rise in the third year to within 5 per cent of the 1943 output.

With specific reference to the system serving the Chicago area, Mr. Bailey showed that in the 10-yr period from 1933 to 1943 industrial sales more than trebled; rural sales grew more slowly and fell off during the last two years; but residential load growth has been steady through good times and bad. Looking to the future for this territory, indications point to doubling the residential load in the first five post-war years; a doubling of the rural load; steady recovery of commercial loads to levels higher than formerly; a tapering off in the railway load; and a reduction in industrial load to the 1940 level, from which it will again begin to rise. Thus it is anticipated that the total system load will be back to present levels at the end of the third post-war year.

In conclusion, Mr. Bailey observed that the utilities have learned from their war experience something about simplification and standardization in the design and construction of equipment and that this will influence post-war practice toward greater economy.

Research in Fuel Burning

The final paper at this session dealt with "Necessity for Research on Combustion Rates and Ash Behavior."[1] The author, **A. R. Mumford** of Combustion Engineering Company, pointed out that present rates in burning are set by troubles encountered with ash and to a lesser extent by losses from incomplete combustion. It is not the average heat releases within a furnace that count so much as those in the "hot spots." This is not the case with liquid fuels which are not associated with ash and with which very high rates of heat liberation are possible. Part of the problem of attaining higher rates of combustion or the elimination of hot spots is the more effective use of available furnace volume. Furthermore, the relation of the factors controlling the ability to secure thorough mixing of the fuel and air is now on an empirical basis and this should be rationalized by research.

With reference to the burning of anthracite, attention was called to the marked "decay" in reactivity shown by particles that have been heated and are carried in suspension with the gases, which property has rendered the re-ignition of partly consumed anthracite especially difficult. Measurements of reactivity of samples in the progress of combustion are desirable as they may lead to the maintenance of hot-spot burning rates in what are now quiescent zones on stokers. Although much investigation on fuel beds has already been done, further studies were indicated.

"If research rationalizes the manner in which higher heat liberation rates and more effective use of available volumes may be obtained, it must also solve some related problems having to do with the design and cooling of the furnace envelope," said Mr. Mumford, who then discussed the relative effectiveness of the liquid phase of water and that of mixtures of liquid and vapor as a cooling medium.

The paper then proceeded to discuss both the chemical and the physical properties of ash and slag which now assume added importance since low ash or ashless fuels do not constitute a sufficiently large proportion of our fuel reserves to warrant optimism. Moreover, 75 per cent of our solid fuel resources are in the central and western fields which contain appreciably more non-combustible material than those in the East.

Turbine Standardization

At the session on Central Station Practice, **M. S. Oldacre** of the Commonwealth Edison Company reported briefly on "Progress Toward Standardization of Turbine-Generators for Central Station Service," as has been under study for the past year and a half by a special joint committee representing the A.S.M.E. and the A.I.E.E. This applies only to large units, as those up to 7500 kw have long been standardized in most respects. The proposals would materially reduce the number of ratings within specified pressure and temperature ranges, as well as limit the extraction points for those sizes and ranges. The net result, it is believed, would be a reduction both in price and in time of delivery. Inasmuch as it has not yet been possible to fit in some factors concerning the generator end of the machines with proposals concerning the steam end, final action has been deferred.

Prevention of Priming and Carryover

A second paper at this session dealt with "Causes and Prevention of Boiler Priming and Solids Carryover." The author, **W. H. Rowand** of Babcock & Wilcox Company, outlined some of the factors which cause the entrainment of boiler water and its attendant salts in the saturated steam leaving a boiler drum and showed the various steps that had been adopted by his company to correct these conditions.

" Since priming is caused by an excessive height of the actual level of the liquid in the drum," said Mr. Rowand, "the obvious way to prevent it is to maintain the actual level below the critical height; and in order to provide a reliable yardstick for the operator, the actual level in the drum should approximate the solid water level shown by the gage glass.

"Foam may be produced by bubbling the steam up through the water in the drum or by impinging a jet of steam and circulating water at high velocity on the surface of the water from above. The height of foam will build up until an equilibrium is reached between the rate of foam formation and the rate at which the foam surface breaks. Since this foam is much lighter than the solid water in the gage glass, its level may

[1] This paper will be reproduced in greater detail in a subsequent issue.

actually be many inches above the level of water in the glass; in some cases there has been as much as 25 in. difference."

Factors which affect the height of the foam layer on the water were listed as operating pressure, steam output per foot of active drum length, quantity of circulating water with the steam, discharge velocity from the riser tubes entering the drum, and quality and quantity of the solids in the boiler water.

It was pointed out that the operator can help to prevent priming and solids carryover in many ways, the most important being (1) regulation of the magnitude and rapidity of load changes, (2) maintenance of proper boiler-water conditions, (3) satisfactory feedwater regulation and automatic combustion control sensitivity, and (4) proper maintenance of the steam separating and purifying equipment in the drum.

Plant Maintenance

William A. Perry, Superintendent of Electric and Power Departments of the Inland Steel Company, presented a comprehensive paper on "Maintenance Systems" in which he outlined the requisites of a successful maintenance plan and how it should be put into effect so that all phases of the work will be properly coordinated. He pointed out how such a plan should be preceded by an educational program all along the line, from the supervisor to the men who do the actual work, and that an objective, in addition to trouble-free operation, should be better trained employees. Moreover, since a well-planned maintenance system makes provision for work being done not only in the years when business is good but also in slack years, the workmen will be interested because it assures a more uniform level of employment.

Maintenance work should also tie in with the safety program. For instance, the operating crew of a steam generator may not always be available to assist the maintenance crew, because of the necessity of looking after other units in service, but they do take the boiler off the line, close the valves, drain the water, and tag all valves. At such times all men working on a job should tag valves, switches, or control switches with their own safety tags.

A plan for scheduled maintenance on a steam generator must be laid out so that all work is done when the unit is down; it cannot be done in sections, and since lengthy outage is not desirable, labor-saving tools should be employed wherever possible. Seasonal factors must also be taken into consideration in overhauling both boilers and steam turbines, as well as certain auxiliary equipment.

Well-kept and accurate records are also necessary to the proper functioning of a maintenance plan and, to quote the author, "No plan would be complete unless it takes into consideration the placing of all replacement parts in first-class condition, bringing these as close as possible to the original or manufacturer's standards."

"Corrosion as a Factor in Piping Maintenance" was the subject of the second paper at this session. The author, **L. G. Vande Bogart,** Research Engineer of the Crane Company, emphasized that the practical solution to many corrosion problems does not depend entirely on the electro-chemistry or chemistry of piping materials, but rather on the physical properties of the fluids handled. Hence, the problem should not be left entirely to chemists and metallurgists, but also concerns the engineer.

Corrosion problems in central stations are almost exclusively associated with the handling of water and steam and successful operation depends upon keeping corrosion as a *potential* rather than an actual cause of piping maintenance. On the other hand, in many industrial plants, especially those involving process work, water treatment may not include complete provision for the prevention of corrosion, and corrosion by water and steam frequently becomes an *actual* cause of piping maintenance.

The author then discussed at length the formation of protective films and stated that "If the ability of a material to resist corrosion by any environment depends on the formation of protective coatings, it is obvious that any factor which prevents such a coating from functioning in its normal manner can be the controlling factor in failures due to corrosion." A familiar example is provided by the impingement corrosion of condenser tubes, where pitting of the inlet end is attributed to the impingement of a stream of water carrying entrained air bubbles. The water is no more corrosive at that point than at any other along the tube, nor is the metal at the inlet any more resistant to corrosion; but the impinging jet disrupts the liquid film or washes away any solid protective coating that may form. Two such phases are likely to exist at locations of maximum turbulence. Other instances of this type have been observed where a phase change from liquid to vapor or vice versa is occurring.

Fuel Oil Outlook

A. L. Foster, Refinery Editor of *The Oil and Gas Journal,* stated that the future status of crude supply remains indefinite as to the discovery of new reserves to replace the present depleted stocks. He predicted that for land use the heavier and poorer grades of oil are foredoomed as competition in post-war days will force the refiner to use as much as possible of the crude as will net the greatest return—principally gasoline and diesel oil. Incidentally, the production of synthetic rubber will require, at the most, only 0.2 of 1 per cent of the available oil.

While the production of aviation fuel is at present utilizing over a million barrels of crude oil per day, it is predicted that 75,000 bbl per day will suffice in the post-war period. As to diesel fuel, Mr. Foster was of the opinion the engine designer who builds for a cetane number of around 45 need expect no difficulty in obtaining satisfactory oil at current, non-premium prices, but that those who demand premium ignition quality fuels must be prepared to pay for them at a considerably higher premium price than heretofore.

War-Time Power Supply

Addressing the "All Engineers' Dinner," **J. A. Krug,** until recently Director of War Utilities, WPB, paid a tribute to the accomplishments of the electric utilities in meeting the demands of war production. He reviewed how in the summer of 1941 the Power Division of WPB had begun the task of gearing power plans to military needs, consistent with existing productive

facilities as to materials and equipment. In this work the utilities had cooperated by loaning the services of many of their engineers.

The original plan had called for the addition of about eleven million kilowatts capacity. However, early in 1942, the needs of the Navy and Maritime Commission for turbines, boilers and other equipment made necessary a re-survey of the most urgent power requirements with the result that the proposed eleven million kilowatts was cut to seven. In fact, it was discovered that some of the earlier reported requirements had been grossly over-estimated. It was also necessary to reassign much equipment intended for plants already started, some of these units being shipped abroad.

It was at this time that the idea of building four 30,000-kw floating power plants was conceived, in order to help out any emergency power shortages that might occur along the inland waterways or the Gulf. One of these barges is now being fitted for use abroad and another is being diverted to Army needs.

Early in this period the construction of some major tie lines was completed with the result that there now exists a power pool for every important industrial section of the country. Such interconnection is the equivalent of $2^1/_2$ million kilowatts of power capacity.

Still another measure adopted was the rescheduling of maintenance and the pooling of operating reserves. Reduction of load through adoption of War Time throughout the country amounted to about $1^1/_2$ million kilowatts and certain voluntary conservation and dim-outs along the coastal areas accounted for additional savings.

The critical year of war production was 1943 and the power supply fully met all requirements without the necessity of curtailment in any necessary services. During that year 3 million kilowatts of central-station capacity were added bringing the total present capacity to approximately 44 million kilowatts. The power outlook for 1944 and 1945 Mr. Krug regarded as very satisfactory.

Other sessions at the conference included papers on electrical subjects and diesel power.

Prof. Stanton E. Winston, Director of the Conference (left) with Charles A. Nash, Conference Secretary

The Combustion Gas Turbine

By F. K. FISCHER* and C. A. MEYER†

The authors show how the relatively low efficiency of the simple open cycle of the gas turbine can be greatly improved by adopting regeneration, intercooling and reheating. High gas temperature is all-important and much depends upon available materials to withstand such temperatures over long periods. Comparison is made with the steam cycle and possible further applications are reviewed.

THERE are many future uses of the gas turbine because it potentially promises higher efficiency at very high temperatures than most engines and prime movers used today. Future applications range from electric power generation to power plants for propelling airplanes, trains and ships.

Advantages of the gas-turbine cycle as compared to the conventional steam system include: (1) no boiler is used; (2) water is not required for the simple open-cycle system; (3) promises greater efficiency improvement at high temperature; (4) high horsepower-per-pound output for short life applications. Present disadvantages include: (1) over-optimism; (2) fuel limited to high-grade oils instead of low-grade oil and coal; (3) little field experience and need of time to complete technical developments in metallurgy and component parts of the gas-turbine system. To a large degree, the future application of the gas turbine depends upon developments in the field of metallurgy, aerodynamics, combustion and heat exchange. Present knowledge in these fields permits building and operating simple gas turbines for certain purposes. Experience with some of the simple forms of gas-turbine plants has been successful and encouraging. In the post-war period, industry will benefit from the developments now being engineered for national defense. These developments will accelerate the application of gas-turbine plants to new and larger fields.

The fundamental directness of the gas-turbine power cycle, in which all the hot gases of combustion are led straight to the turbine, has intrigued engineers for years. Leonardo da Vinci devised a crude version. In 1791, John Barber, an Englishman, took out the first patent on a turbine operated by gases. Since that time there has been an almost continuous stream of developments.

Progress toward a practical gas-turbine power unit has been delayed because the thermal efficiency required to make it competitive with the highly developed steam cycle required operation above 1000 F a highly efficient compressor, and a highly efficient turbine. Two seemingly unrelated industries have recently made important contributions to help solve these problems. Metallurgists, in developing materials for superchargers, have produced alloys that are expected to withstand at least 1200 F continuous service at the low operating pressures encountered in gas turbine work. Aviation and wind tunnel researches on airplane propellers and wings have contributed fundamental aerodynamic data on which high efficiency compressor designs are based. The research in these two industries plus the accumulated steam experience of many years have made possible the necessary high-efficiency turbine and compressor elements and solved many of the mechanical problems involved in gas turbines.

In the combustion gas-turbine system of power generation there are two basic cycles, namely, the open cycle for moderate capacities and the closed cycle for large units.

The gas turbine employs the simplest power cycle known, consisting of three major elements: a compressor, a combustor and a gas turbine. A general idea of what the elements are like is shown as longitudinal sections in relative size in Fig. 1. The gas turbine resembles the straight reaction, non-condensing steam turbine. The blades look more like air-foil sections than reaction

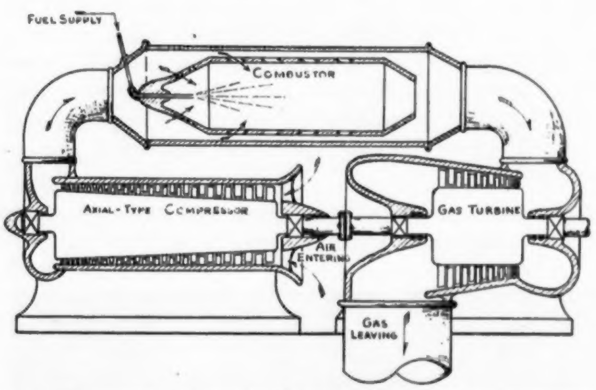


Fig. 1—Elements of gas-turbine cycle are a compressor, a combustor and a gas turbine

steam-turbine blades due to the small pressure drop and large gas volume involved. The axial-flow compressor also resembles a straight reaction turbine, with the gas to be compressed passing axially through the compressor. Action of the blades in the axial flow compressor is the reverse of the action of expansion in a reaction turbine. This physically small compressor handles the large volume of gas efficiently. The combustor is the burner in which the chemical energy of the fuel oil is converted into heat energy, by burning the fuel with sufficient excess air to obtain the desired temperature. The hot product of combustion from the combustor is the gas, which, expanding to a lower pressure and temperature in the turbine, converts some of its heat energy into mechanical energy at the turbine shaft. The combustor is relatively small since its rate of heat release is many times

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that of the conventional steam boiler which, in addition to burning fuel, must transfer the heat through tube walls to generate steam.

How Cycle Works

The combustion gas-turbine cycle in its basic form comprises the three major elements previously mentioned: the compressor, combustor and gas turbine, plus a generator or shaft for transmitting the useful power output, and a means of starting. This simple arrangement is called the open-cycle system. To start a combustion gas turbine some external means, such as a motor, is required. This is necessary as the air for combustion is supplied to the combustor by the compressor. When the unit is in operation the energy to drive the compressor comes from the expansion of the products of combustion in the gas turbine.

In the simple cycle operating at 1200 F, the products of combustion contain some 600 per cent excess air. This gas is expanded in the turbine and exhausted to the atmosphere. No intermediate fluid is used as in the steam cycle. Because the simple open combustion gas cycle does not require cooling water, no steam condenser such as used in the condensing steam cycle is needed and plants may be located without regard to a suitable source of cooling water.

Although the first patent was taken out over 150 years ago, early inventors were unsuccessful in getting units efficient enough to drive their own compressor. The cycle was perfectly sound, but these early inventors lacked materials to withstand the necessary high temperature plus turbines and compressors of suitable efficiency.

Today the story is changing. Materials are capable of operating at high temperatures. The maximum temperature employed is largely a question of the useful life. For a life of relatively few hours, such as might be satisfactory for some military needs, temperatures of the order of 2000 F are allowable. Heavy-duty or long-life applications are limited to much lower temperatures. The tremendous advances in metallurgy for the war effort will undoubtedly produce materials capable of operation at temperatures which we would not have attained for many years under a normal peacetime development.

Turbine and Compressor Efficiency

In the gas-turbine cycle, the useful power output depends upon obtaining relatively high turbine and

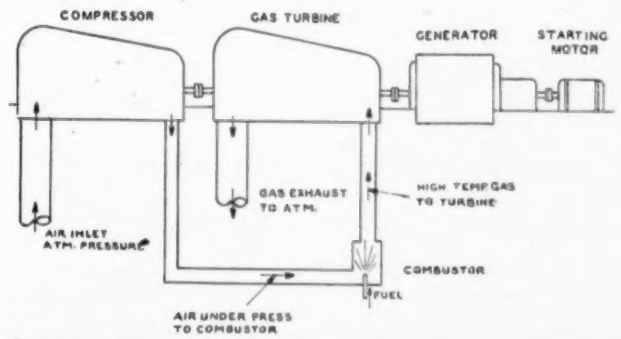


Fig. 2—Simple open cycle of combustion gas turbine

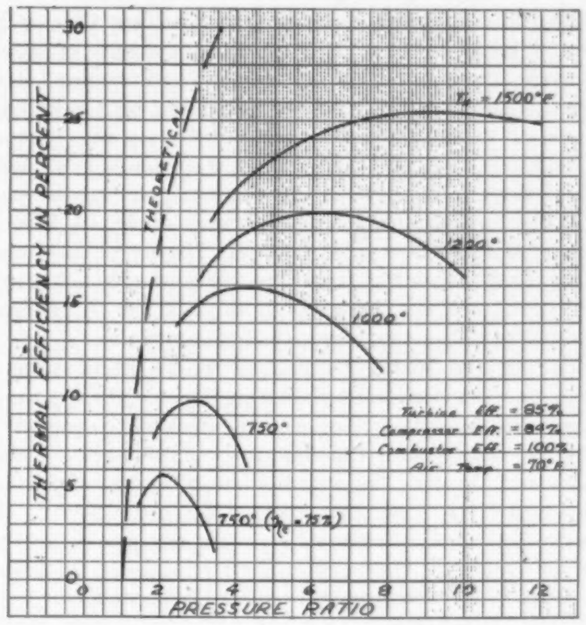


Fig. 3—Effect of pressure ratio on thermal efficiency of open-cycle gas turbine. Assumed efficiencies: turbine 85 per cent, compressor 84 per cent, combustor 100 per cent. Air temperature 70 F

compressor efficiency. The useful net output is the difference between the total turbine output and the work consumed by the compressor in compressing the air. With the system of Fig. 2 operating at a top temperature of 1200 F, for each useful unit of power output, the turbine develops 3.95 units of which 2.95 are needed to drive the compressor. A reduction of 1 per cent in the efficiency of each of these elements reduces the useful output by 7 per cent. The useful output decreases sharply as the top temperature is lowered.

In Fig. 3 the simple gas cycle thermal efficiency is plotted as a function of the pressure ratio for several turbine-inlet temperatures of the combustion gas. Pressure ratio is the compressor discharge pressure divided by the compressor inlet pressure, which is 14.7 psi abs in the open cycle. The curves are based on the following efficiencies: turbine 85 per cent; compressor 84 per cent; combustor 100 per cent; and air inlet temperature of 70 F. The 750-F curve is plotted for two different compressor efficiencies showing the effect of,change in efficiency of one of the elements. A reduction in compressor efficiency of 9 per cent cuts the cycle efficiency almost in half. The relatively low pressure ratios at which maximum efficiency is obtained, around 6 for 1200 F, means that relatively low turbine-inlet pressures exist in the open cycle, under 100 psi abs Low pressure results in large gas volume and relatively large turbine blade dimensions.

Regenerating, Intercooling and Reheating Aid Efficiency

As shown in Fig. 3 the efficiency of the simple open gas cycle is low unless extremely high temperatures are used. However, there are three practical ways of greatly improving the gas-cycle efficiency, namely, regenerating, intercooling and reheating. The regenerating gas cycle is one in which a heat exchanger (regenerator) transfers some of the heat from the relatively hot exhaust gases leaving the turbine to the air before it

enters the combustor (see Fig. 4). Heating the air by exhaust gases reduces fuel consumption and improves the cycle efficiency. The amount of heat obtained from the exhaust gas depends on the size of the heat exhanger. This is an economic problem in which gain in efficiency is balanced against cost of heat-exchanger surface. Calculations indicate that the economic size of the heat exchanger will limit the regenerating cycle, at 1200 F inlet temperature, to approximately 75 per cent recovery of the heat available from the turbine exhaust gases. This economic size will be about 0.30 cu ft of heat-exchanger volume per kilowatt of capacity.

Efficiency is further improved when intercooling is added to regeneration as shown in Fig. 5. As the name implies, intercooling removes the heat of compression from the air passing through the compressor. Water, circulating through the intercooler, cools the air and is a necessary part of the cycle. By intercooling, the compressor work is reduced because the colder air has smaller volume. Other conditions remaining the same, one stage of intercooling will reduce the compressor work by some 15 per cent. This increases the portion of the turbine capacity available as useful output and improves the cycle efficiency. A large number of intercoolers is ideal but probably only a few stages will be practical.

The third method of improving efficiency, reheating, consists of adding heat to the gas as it passes through the turbine as shown in Fig. 6. The gas-turbine reheat cycle is the same principle as the reheat cycle used in many steam plants, but in practice it will bear little resemblance. Reheating in the gas turbine will consist of burning fuel directly in the gas (approximately 85 per cent air) passing through the turbine. Here again, the practical number of reheats is limited. One reheat is illustrated in Fig. 6.

Reheating and intercooling increase the amount of useful energy per pound of working gas passing through the system, thus reducing the number of pounds of working medium circulated. Therefore, the size of piping and blade path in the compressor and turbine is reduced. In combination with a regenerator, the terminal difference across the heat exchanger is greater for a given size exchanger, or a smaller heat exchanger transfers the original amount of heat. In partial load operation they increase the partial load efficiency by a considerable amount.

Various Cycle Combinations Compared

The combination of regenerating, reheating and intercooling is shown in Fig. 7. Different cycle arrangements are compared in Table I on the basis of the power requirements of each major element, with the capacity of the generator as unity. The efficiency of each cycle arrangement at 1200 F is given, the temperature in degrees F, and the absolute pressure at different points in each cycle.

The thermal efficiency of the open-cycle gas turbine for various combinations of regenerating, reheating and intercooling is shown in Fig. 8. This gives the relative value of these modifications and a general idea as possible applications of this cycle. The temperature range of 1000 to 1500 F was chosen because applications at temperatures much below 1000 F will undoubtedly be impractical. Early applications for heavy-duty

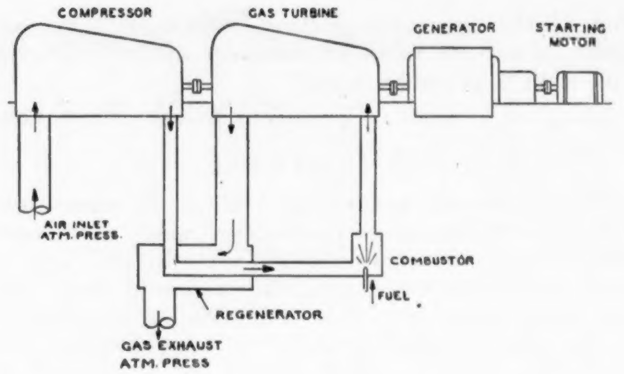


Fig. 4—Regeneration applied to open gas-turbine cycle

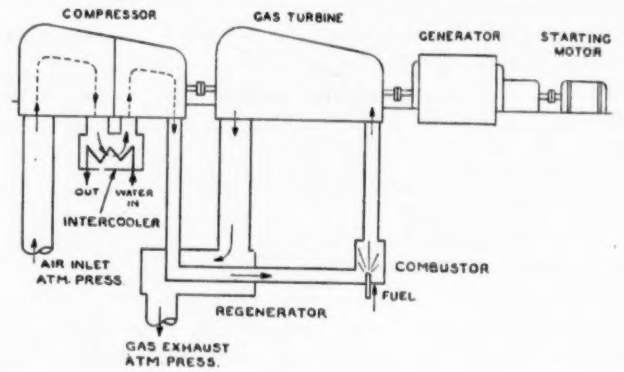


Fig. 5—Intercooling and regeneration for the open cycle

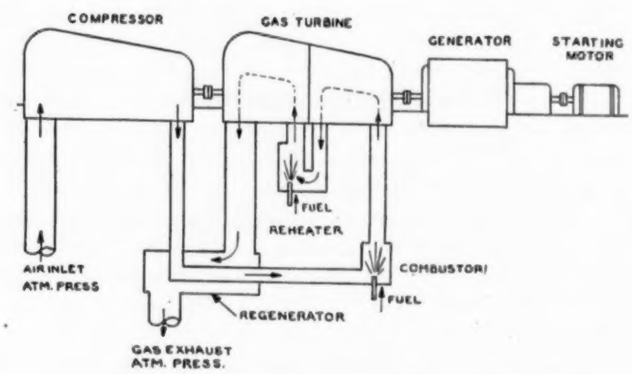


Fig. 6—Reheat and regeneration for open cycle

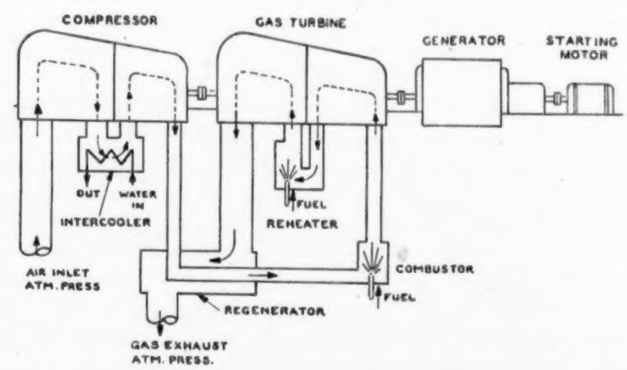


Fig. 7—Intercooling, reheat and regeneration for open cycle

long-life apparatus will probably not exceed temperatures of 1200 F with 1500 F and higher limits awaiting future developments in metallurgy.

The temperature of the inlet air to the compressor has a marked effect on cycle efficiency. In contrast with steam plants the colder this inlet air the higher the cycle efficiency and capacity. In the simple open cycle, changing the inlet air temperature 10 F changes the cycle efficiency 0.74 point or approximately 3 per cent per 10 deg F change. The effect on capacity is approximately 4 per cent per 10 deg F change. The effect on cycle thermal efficiency of inlet air temperature, on the different cycle arrangements with a top temperature of 1200 F, is plotted in Fig. 9.

TABLE I—EFFECT OF DIFFERENT OPEN-CYCLE ARRANGEMENTS ON EACH MAJOR ELEMENT

Item	Simple Cycle	Cycle with Regeneration	Intercool and Regenerate	Reheat and Regenerate	Intercool, Reheat and Regenerate
Fig. No.	2	4	5	6	7
Input in fuel	4.95	3.75	3.43	3.55	3.11
Turbine rating	3.95	2.95	2.80	2.88	2.55
Compressor power	2.95	1.95	1.80	1.88	1.55
Useful output	1.00	1.00	1.00	1.00	1.00
% Eff. at 1200 F	20.2	26.6	29.2	28.1	32.2
Gas temp., deg F at					
Turbine inlet	1200	1200	1200	1200	1200
Leaving reheater	..	..	..	1200	1200
Turbine exhaust	635	790	695	920	865
Leaving regenerator	..	455	350	560	520
Air temp., deg F at					
Compressor inlet	70	70	70	70	70
Leaving intercooler	..	..	70	..	..
Leaving compressor	490	340	230	440	405
Entering combustor	490	680	575	800	750
Press., psi abs at					
Compressor inlet	14.7	14.7	14.7	14.7	14.7
Compressor discharge	88.2	51.5	73.5	73.5	102.9
Turbine inlet	88.2	50.2	71.7	71.7	100.4
Turbine exhaust	14.7	15.1	15.1	15.1	15.1

Steam and Combustion Gas Cycles Compared

Because steam is the most widely used medium for transferring heat into mechanical energy, a comparison of the steam cycle and the gas cycle may help in judging the gas cycle and its possibilities. In judging the efficiency of power cycles, a 100 per cent thermal efficiency is not obtainable as the temperature of the cold body is far above the absolute zero of temperature. The Carnot Cycle is a theoretically perfect cycle, and no cycle operating between the same hot- and cold-body temperatures can have a better thermal efficiency. The best any cycle can hope to do, when operating under the same conditions, is to attain the Carnot Cycle efficiency. The gas turbine cycle can theoretically give the same efficiency as the Carnot Cycle. This is only *theoretically* possible because it requires 100 per cent efficiency of the gas turbine and compressor, an infinite number of stages of intercooling and reheating, and a regenerator infinite in size.

The steam cycle theoretically offers the Carnot Cycle efficiency only up to the critical pressure (705.4 F; 3206 psi abs). Above this temperature, the gap between the steam cycle and the ideal cycle gradually widens as the temperature is increased. From a purely theoretical standpoint the combustion gas-turbine cycle holds forth greater promise of efficiency than the steam cycle.

Of more value are the thermal efficiencies obtainable in practical applications. Fig. 10° compares the best efficiencies obtained in large central-station power plants (projected to 2000 F) with the expected practical limit in efficiency of the large capacity closed-cycle combustion gas-turbine power plants. Above 1000 F the gas-cycle efficiency increases approximately three times as fast as the steam-cycle efficiency for a given top temperature increase.

It is expected that the gas-turbine cycle efficiency will not be greatly affected by unit size, and this combustion gas-cycle curve can also be interpreted as applying to open-cycle gas turbine power plants of relatively small capacity. Economic steam plants for capacities around 5000 kw seldom exceed 25 per cent overall thermal efficiency. This would indicate a considerable efficiency advantage, in small units, in favor of the gas cycle,

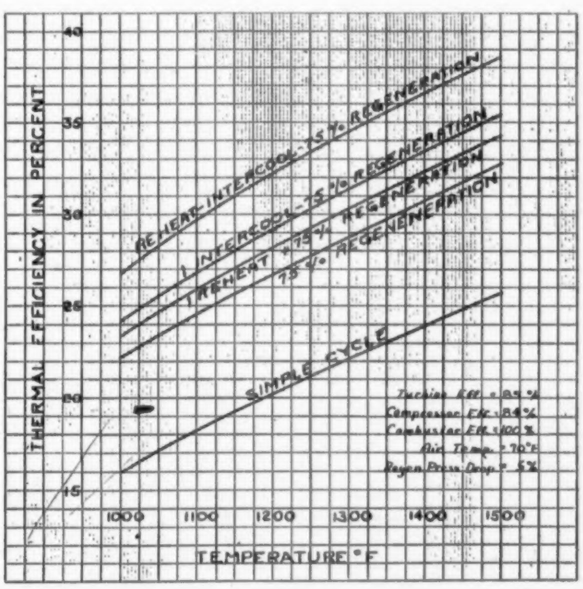


Fig. 8—Effect of reheat, intercooling and regeneration on thermal efficiency over range 1000 to 1500 F, based on 70 F and 5 per cent pressure drop in regenerator. Assumed efficiencies: turbine 85 per cent, compressor 84 per cent, combustor 100 per cent

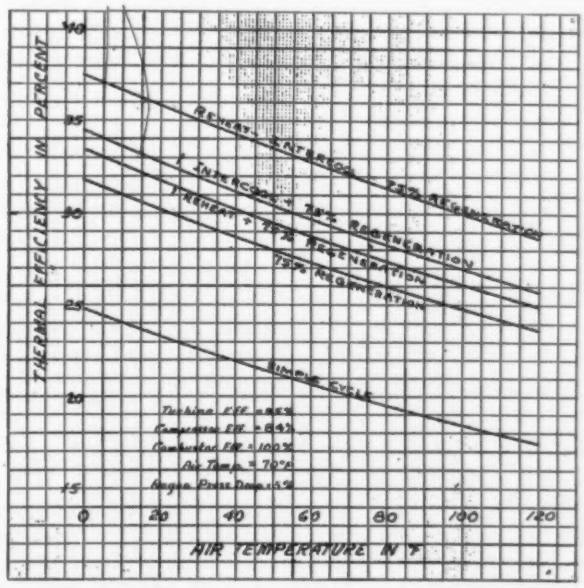


Fig. 9—Effect of air temperature on thermal efficiency of open cycle gas turbine with 1200 F inlet gas temperature. Efficiencies and regenerator pressure drop are the same as in Fig. 8

provided economics permit designing it for anywhere near its maximum possible efficiency.

A 3600-rpm, 5000-kw steam turbine is compared with a 3600-rpm, 5000-kw net output open-cycle gas turbine in Table II. The first column covers the simple cycle without reheat, intercooling or regeneration. Columns 2 and 3 make the comparison or a 5000-kw net output gas-turbine cycle using one intercooling, one reheat and regeneration. Column 4 deals with a 5000-kw steam turbine. This comparison indicates the low pressure in the open-cycle gas turbine as compared with the steam cycle. As a result, the energy per pound of gas is small and the flow of gas is very large; 510,000 lb per hr for the simple-cycle gas turbine as compared to 52,500 lb per hr of steam to the steam turbine. The large flow and low pressure to the inlet of the gas turbine gives a large volume flow which means the piping and blading of the gas-turbine inlet are large compared to the steam turbine

TABLE II—COMPARISON OF COMBUSTION GAS TURBINE AND STEAM TURBINE

5000 Kw Rating—3600 r.p.m.

	Open-Cycle Gas Turbine: Simple Cycle Single Cyl.	Open-Cycle Gas Turbine: One Reheat, one Intercool and Regeneration H.-P. Turbine	One Reheat, one Intercool and Regeneration L.-P. Turbine	Steam Turbine 3 Stages F.W.H. Single Cyl.
Inlet Press., psi abs	88.2	100.4	39.4	465
Inlet Temp., deg F.	1200	1200	1200	825
Exhaust Press., psi abs	14.7	39.4	15.1	3/4
Steam or gas rate, lb/kwhr	102	56		10.5
Full load flow, lb/hr	510,000	280,000		52,500
Inlet vol flow, cu ft/sec	990	475		24.8
Exhaust vol flow, cu ft/sec	3900		3250	6120
Ratio (exhaust vol. ÷ inlet vol.)	3.95	6.85		250
Turbine floor area, sq ft	160	150	155	100 (Turb. room only)
Net generator output, kw	5000	5000		5000
Approx. plant thermal eff., %	18.4*	29.4*		23.6

* Inlet air temp. 70 F.

The ratio of exhaust to inlet volume is small for the gas turbine. This makes a balanced blade path unlike that of the steam turbine, which in this case must handle an exhaust volume 250 times as great as the inlet volume. The large blade dimensions limit the maximum net output rating of the open-cycle, single-flow, combustion gas turbine to approximately 7500 kw. However, the injection of liquids presents a theoretical possibility considerably extending this limit.

Closed Cycle for Large Units

The closed cycle offers a method of increasing the maximum capacity of the open cycle. The volume of the working gas is inversely proportional to the absolute pressure. If the pressure is multiplied by 10, the size is divided by 10. In the closed cycle, the circulating working gas is at a relatively high pressure and reduces the physical size of compressor and turbine. To reduce the temperature of the gases before they enter the compressor, cooling water is required in the closed cycle. The heat exchanger in which the gas is cooled before it enters the compressor is called a gas precooler. The amount of heat given up to the cooling water is equivalent to that removed in the condenser of a steam unit of equal capacity. The quantity of cooling water required will be less, as a higher water temperature rise is permissible.

The closed cycle shown in Fig. 11 is the one used by Escher Wyss (Swiss). This is an externally fired cycle in which the products of combustion do not pass through the gas turbine and compressor. The working gas (air, hydrogen or other medium) operates at a relatively high pressure in a closed, recirculating circuit. In the gas heater, the heat from the products of combustion is transferred to the working gas which then expands in the turbine to a lower pressure. The gas heater in this cycle corresponds to the steam boiler in the steam cycle. For a practical efficiency, it will be larger than the modern steam boiler because gases are on both sides of the gas heater. This cycle is very similar to the steam cycle, except that the working fluid does not undergo a change of state. As this closed cycle keeps the products of combustion out of the turbine and compressor circuit, the problem of using coal as a fuel should be much simpler of solution than in those cycles which circulate the products of combustion.

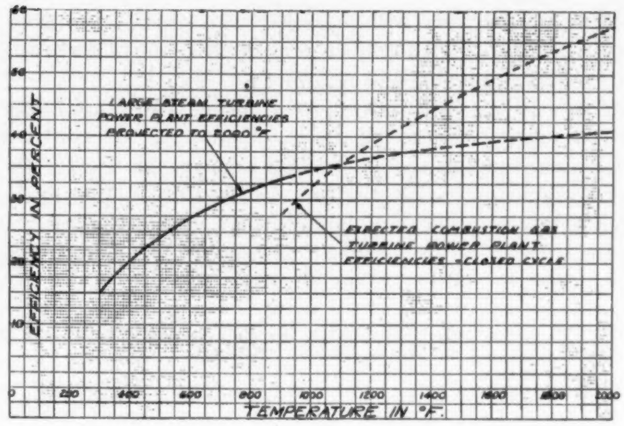


Fig. 10—Efficiencies compared for best practical steam power plants and combustion gas-turbine plants

Hydrogen Has Advantages

In the closed cycle, the compressor inlet pressure will be maintained at approximately 150 psi with a discharge pressure of some 600 psi. This high pressure greatly reduces the size of turbine and compressor and should permit maximum ratings to be built approaching those in the steam cycle. Some gas other than air will probably be used as the working medium in the externally fired closed cycle. Hydrogen, for example, has properties which make it far superior to air for this application. The density of hydrogen is one-fourteenth that of air, the specific heat is fourteen times that of air, and the thermal conductivity is 6.8 times that of air.

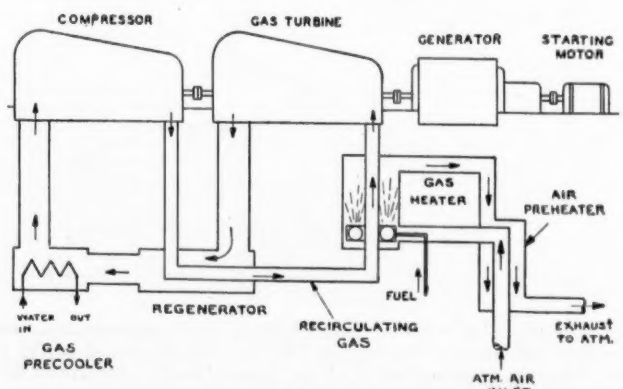


Fig. 11—Escher Wyss externally fired closed cycle

New Cycle Studied

A closed cycle system under development by Westinghouse is shown in Fig. 12. In this a separate gas turbine and compressor are used to pump up the cycle on which the main gas turbine and compressor operate. High pressure of around 600 psi may be used with a compressor inlet pressure of around 150 psi. The main gas turbine and compressor would be small as they operate at high pressure. This cycle is internally fired, the products of combustion passing through the gas turbines and the main compressor. Enough makeup air is continually supplied to maintain pressure and support combustion. It is supplied by a compressor which is driven by a second gas turbine. This cycle avoids the large gas heater required by the Escher Wyss cycle, but it requires an extra gas turbine and compressor to pump up the system. Solid matter from the fuel must be removed.

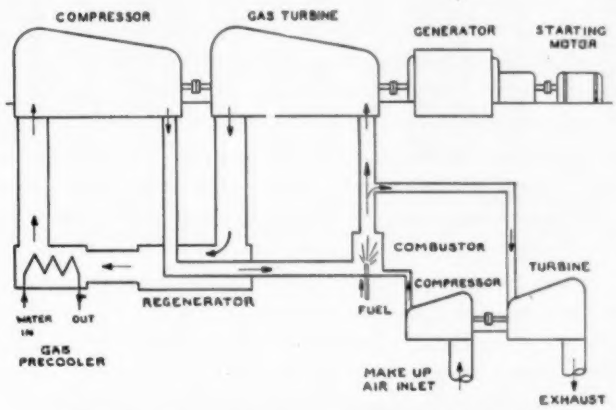


Fig. 12—Proposed internally fired closed cycle

In the closed cycles shown in Figs. 11 and 12, reheating and intercooling are not illustrated. However, they offer the same advantage in the closed cycle that they offer in the open cycle. The biggest single additional problem in the closed cycle is a method of building practical heat exchangers. The problem is further complicated by the fact that the gases will carry foreign matter from combustion which may both corrode and erode the exchanger and reduce the heat transfer rate by depositing foreign material on the transfer surface.

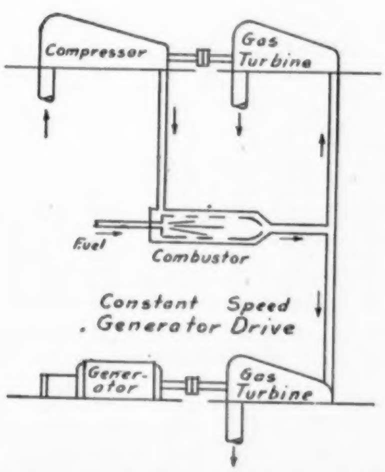


Fig. 13—Possible method of gas-turbine control combining variable- and constant-speed drives

Gas-Turbine Control

Combustion gas-turbine control can be simple and reliable, consisting only of control of the gas temperature by controlling the rate of fuel supply. Governing valves, such as used in steam-turbine control, are not needed. Efficient partial load performance can be obtained by using two turbines—one variable-speed turbine driving a compressor, plus a constant-speed turbine driving a generator (see Fig. 13). The use of regenerators, reheaters and intercoolers, in addition to improving the full load economy, have an even greater effect in improving the partial load economy. In the closed cycle, by reducing the gas pressure as the load is reduced, practically full-load efficiency can be maintained at partial loads.

Possible Gas-Turbine Applications

The possible applications of the gas turbine are many, ranging from a simple open cycle for small capacities to a closed cycle for large ratings; for example:

Locomotives

The simple open gas cycle requires no water. It has low weight and small space requirements combined with simplicity. With an efficiency of 20 per cent at 1200 F and the expected low maintenance of turbine drives, it should prove a good power plant for a locomotive. The inability of the gas turbine to operate in reverse makes either electric drive or the development of a satisfactory reversing gear necessary for this application.

Airplanes

For relatively small power outputs, such as required by airplanes, the gas turbine operating at high speed and high temperature to obtain maximum rating per unit weight of material, has real possibilities.

Ship Drives

The combustion gas cycle offers efficiencies equal to the best modern marine steam power plants, which have overall efficiencies of approximately 25 per cent. Weight and space requirements of equipment are a real factor in this application. The gas cycle eliminates the steam generator and steam condenser. The advantage in weight and space undoubtedly will favor the gas cycle, despite the gas compressor, the regenerator heat exchanger, and the large gas turbine. The requirement of astern operation in marine service handicaps the gas turbine, except for electric drive.

Power

General application of the combustion gas cycle in the power-generation field probably will not take place until the problems in connection with the use of coal as a fuel are solved. The successful development of the closed cycle is necessary if units of very large capacity are to be built. The maximum capacity for which units can be built in the open cycle will include the majority of industrial applications. There are many special applications in the power-generation field in which the open gas cycle will possibly find early application, such as emergency standby service, and low first cost units at the ends of transmission lines.

Processing

In the industrial field where both power and process steam are required the gas turbine has possibilities. It

fits well in those applications where the steam required is relatively small in relation to the power load. This is different from the extraction steam turbine where large quantities of process steam per kilowatt are necessary to attain a comparably efficient cycle. Here again, the use of coal as a fuel is necessary for a wide general application.

Problems Ahead

In drawing conclusions, it should be remembered that the cycle has only had practical application in very special cases. The full possibilities of any cycle can only be evaluated from successful proof of its economy, first cost, maintenance cost and reliability. The addition of elements which improve the fuel economy, and arrangements of the cycle for large capacities, are obtained at a sacrifice in simplicity and at a price. The development of the best system is expected to be costly in time and money.

Metallurgy plays an important part in the gas cycle as the efficiency increases rapidly with increase in top temperature. To obtain materials suitable for operation at higher temperatures the metallurgists are looking at materials similar to the non-forgeable and non-machinable tool steels. The method of forming these alloys to shape, such as precision casting to size, may revolutionize accepted methods of manufacture. To apply such materials their additional first cost and manufacturing cost must be justified. Any application of such materials must be preceded by careful tests. For heavy-duty apparatus these tests must extend over long periods before the designer can use them with safety. Careful differentiation between applications as to required length of life of apparatus is necessary. The fact that a piece of equipment is operated at 1800 F for a life of a few hours does not mean temperatures of that order can be used for heavy-duty applications.

Present developments of the gas turbine are limited to the use of relatively high-grade fuel oils. This one factor is a serious handicap to the gas cycle. There is considerable evidence that oil is being used at a greater rate than new supplies are being found. So in the post-war period necessity may dictate a prime mover which can use coal as a fuel. The gas cycle is definitely limited in application until such time as the problems in connection with the burning of low-grade oil and coal are successfully solved.

Present research efforts are being expended in developments for national defense. In the post-war era industry will have access to the developments in the gas-turbine field and to developments in high-temperature materials. These may considerably change present thinking. It is safe to predict that general applications of the gas cycle must wait until the post-war era.

It will be wise to watch the developments of the early installations before attempting to make widespread applications. At present, conclusions as to the ultimate possibilities of the gas cycle are little more than good guesses. The gas-turbine art must advance beyond its present early development stages before it can be judged with assurance. However, undoubtedly it will find real usefulness in a large number of fields, possibly complementing rather than competing with the steam turbine. Just how and where the gas turbine will be applied, only time will tell.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1943 Water Tube		1942 Water Tube		1943 Fire Tube		1942 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	11	64,169	197	1,590,796	‡16	‡18,888	52	59,476
Feb.	‡32	‡164,800	216	1,467,900	‡237	‡146,834	58	83,647
Mar.	‡31	‡147,937	268	1,487,505	‡16	‡24,293	60	62,679
Apr.	‡95	‡361,746	422	2,402,579	‡21	‡32,392	46	61,054
May	127	683,052	156	1,243,328	9	14,106	57	83,147
June	‡163	‡679,306	139	847,562	25	41,073	57	74,231
July	31	222,253	133	880,430	‡18	‡9,549	45	53,596
Aug.	51	311,448	113	933,660	‡30	‡38,797	26	30,228
Sept.	‡40	‡145,587	48	378,096	‡38	‡40,599	337	275,808
Oct.	107	390,862	151	1,048,117	‡26	‡34,542	14	24,611
Nov.	52	‡273,488	48	241,155	13	19,470	21	24,470
Dec.	87	1,035,005	162	973,214	27	53,312	6	9,613
Jan.-Dec., incl.	827	4,479,653	2,027	13,278,139	473	473,855	773	836,183

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period Jan. to Dec. (incl.), 1943, 42,062,000 lb per hr; in 1942, 112,985,000 lb per hr.

	1944 Water Tube		1943 Water Tube		1944 Fire Tube		1943 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft	No.	Sq Ft
Jan.	36	226,537	11	64,189	24	31,701	16	18,888
Feb.	39	256,942	32	164,800	28	43,341	237	146,834
Mar.	47	229,121	31	147,937	44	53,893	16	24,293
Jan.-Mar., incl.	122	712,600	74	376,926	96	128,935	269	190,015

Total steam generating capacity of water tube boilers sold in the period Jan. to Mar. (incl.) 1944, 5,826,000 lb per hr; in 1943, 2,745,000 lb per hr.

* Includes water wall heating surface.

Marine Boiler Sales

	1943 Water Tube		1942 Water Tube		1943 Scotch		1942 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	‡597	‡2,185,483	237	1,119,437	1	1,080	–	—
Feb.	31	102,404	70	347,324	–	—	–	—
Mar.	‡182	‡494,307	1,676	7,827,106	1	2,565	–	—
Apr.	19	85,244	236	848,986	2	5,130	1	161
May	1,000	‡4,985,280	364	1,473,354	3	6,401	2	868
June	895	4,241,507	255	876,146	1	2,565	–	—
July	386	1,852,389	242	1,038,918	1	2,565	–	—
Aug.	‡729	‡3,320,329	204	665,660	4	7,730	–	—
Sept.	‡74	‡321,124	666	2,596,342	2	5,130	–	—
Oct.	39	‡166,373	261	1,549,265	2	5,130	–	—
Nov.	‡94	‡368,005	208	1,169,561	1	988	–	—
Dec.	66	309,682	396	1,448,225	2	1,976	–	—
Jan.-Dec., incl.	4,112	18,432,127	4,815	20,950,824	20	41,260	3	1,029

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period Jan. to Dec. (incl.) 1943, 185,487,000 lb per hr; in 1942, 254,812,000 lb per hr.

	1944 Water Tube		1943 Water Tube		1944 Scotch		1943 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	49	273,879	597	2,185,483	—	—	1	1,080
Feb.	96	507,658	31	102,404	30	9,000	–	—
Mar.	70	226,166	‡156	‡430,841	38	9,700	1	2,565
Jan.-Mar., incl.	215	1,007,703	784	2,718,728	68	18,700	2	3,645

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period Jan. to Mar. (incl.) 1944, 12,969,000 lb per hr; in 1943, 39,268,000 lb per hr.

† Mechanical Stoker Sales

	1943 Water Tube		1942 Water Tube		1943 Fire Tube		1942 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	‡131	‡46,948	87	42,876	457	31,623	159	24,135
Feb.	‡106	‡34,685	131	55,001	575	83,673	185	26,889
Mar.	114	48,367	84	46,055	‡571	‡77,729	210	31,329
Apr.	‡96	‡32,251	102	49,061	‡432	‡64,022	313	39,877
May	96	39,640	125	44,069	414	57,889	206	33,566
June	118	61,415	123	48,267	‡366	‡48,962	296	49,760
July	‡98	‡50,992	131	59,376	‡379	‡52,680	297	45,902
Aug.	68	31,377	94	40,619	446	62,732	295	49,725
Sept.	49	18,911	78	37,081	446	55,496	295	44,910
Oct.	159	53,382	85	26,633	391	54,477	353	49,575
Nov.	57	21,619	120	59,799	‡247	‡33,495	333	49,799
Dec.	60	41,853	69	24,140	204	25,712	316	51,947
Jan.-Dec., incl.	1,152	481,440	1,239	532,977	4,928	648,490	3,258	497,414

† Capacity over 300 lb of coal per hour. ‡ Revised.

	1944 Water Tube		1943 Water Tube		1944 Fire Tube		1942 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	35	13,982	131	46,948	147	20,761	457	31,623
Feb.	35	18,437	106	34,685	156	22,495	575	83,673
Mar.	56	20,128	114	48,367	142	5,660	571	77,729
Jan.-Mar., incl.	126	52,547	351	130,000	445	48,916	1,603	193,025

Addition to Capacity and Modernization of MARYSVILLE POWER HOUSE—V

This is the concluding installment of a series of five articles in which the addition of a 75,000-kw turbine-generator to the Marysville Power House has been described. The reasons for adding capacity at Marysville and the basis for the selection of 815 psi, 900 F, as the throttle steam condition were reviewed in the first article. The fuel-burning equipment, steam generators, turbine-generator and associated equipment were described in subsequent articles. The first part of this installment covers the design and arrangement of the principal piping systems; the second part, gives operating results based on twelve months' experience with the enlarged plant. An equipment list is appended.

By H. E. MACOMBER

The Detroit Edison Company

THE fundamental principles used in designing the piping for various services in recent extensions of Detroit Edison power plants have been discussed at length in articles describing the Conners Creek and Delray plants. That for the Marysville addition follows the same general principles. The low-pressure piping, such as condensate, general service and the like, follow rather conventional practice and therefore are not described here. Although high-pressure drip-piping, blowoff piping and bleeder-steam piping all required special consideration, the designs, with minor exceptions, are the same as those at Delray.

The superheated-steam and boiler-feed piping, on the other hand, include a number of improvements and simplifications which should be of interest. Accordingly, full descriptions of these two systems are given in this article.

Piping Materials and Standards

The materials and dimensional standards of all piping used in the Marysville addition are given in the accompanying table. Carbon-molybdenum pipe for superheated steam service was purchased to A.S.T.M. Spec. A206-40T. This pipe, in sizes four inch and larger, was tested in accordance with the supplementary requirements of that specification, and photomicrographs of each size and heat were obtained of pipe in the "as-rolled with 1200 F stress relief" condition. In addition, Charpy V-notch impact tests were made on rings from the 12-in. and 14-in. pipe to determine whether it was suitable for use as straight fillers without further heat treatment. Since the pipe was found to have acceptable grain size and structure, and adequate impact values, fillers were used in the mill-finished condition. Carbon-moly bends were normalized at 1725 F ± 25 F, and the final condition checked as to grain size and structure, and impact resistance. The pipe was inspected by a Detroit Edison inspector at the pipe mill and during fabrication of the bends to insure that all possible precautions were taken, and that an adequate record of each piece was maintained.

Valve bodies for superheated steam service originally were specified as chrome-nickel-moly, Grade WC4, of A.S.T.M. Spec. A217. Subsequent limitations on use of chromium and nickel resulted in the substitution of carbon-moly, Grade WCl, of A.S.T.M. Spec. A217, for two of the three stop and check valves and for the valve in the turbine lead. The improved means of controlling superheated steam temperature by tilting the burner nozzles, in addition to manipulation of the flue gas diversion damper, as described earlier in connection with the fuel burning equipment, should avoid excessive temperature swings and enable both valve body materials to perform satisfactorily.

Pipe used for the feedwater system was medium carbon steel, Grade B of A.S.T.M. Spec. A106. In that part of the system from the boiler-feed pump to the second stop valve preceding the economizer, Schedule 80 ASA B36-10 pipe was used. From this point to the economizer, Schedule 100 pipe was employed. The standard used for the bypass around the feedwater regulator valve was Schedule 120.

To meet the Boiler Code requirements for a boiler drum pressure of 975 psi, it was necessary to use either 900-lb carbon-moly bodies or 1500-lb carbon-steel valve bodies in the piping from the economizer to and including the second stop valve. It was decided to use the 900-lb carbon-moly valves because the cost was less. Although 900-lb carbon-steel valves would have been adequate in the remainder of the feedwater system, carbon-moly valves were used so that all valves in the feedwater piping would be interchangeable.

Inasmuch as Mr. Macomber has been on government work in Washington for the greater part of the past seven months, a considerable amount of work in completing the later installments of this series has fallen upon Mr. F. D. Campbell of The Detroit Edison Company, and the second part of the present article, dealing with operating results, was prepared by Mr. R. M. Van Duzer, Jr. Engineer of the Production Department of that company. We are greatly indebted to both for their assistance.—EDITOR.

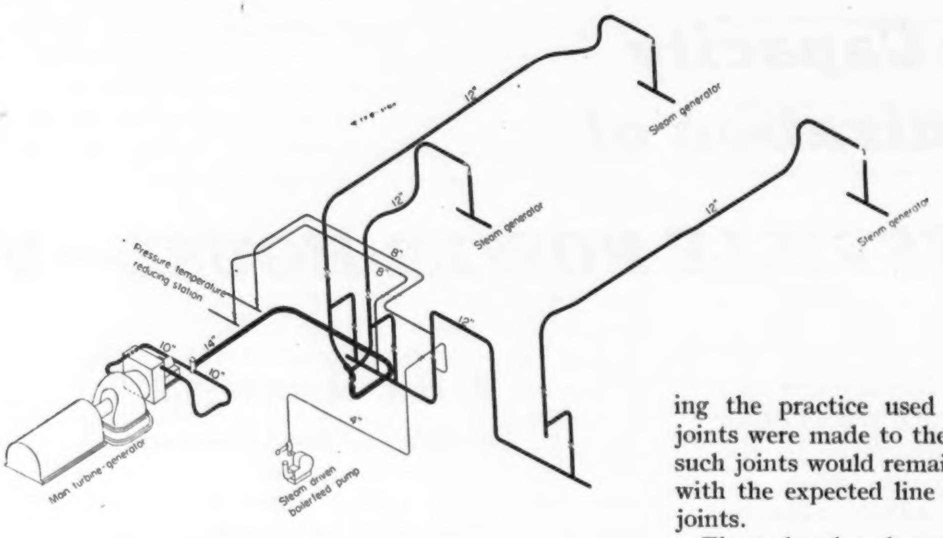


Fig. 59—Isometric drawing of superheated steam piping

Superheated Steam Piping

The general arrangement of the superheated steam piping is shown in the isometric drawing reproduced in Fig. 59. Although the arrangement is similar to that used in the high-pressure section at Delray, a number of improvements and simplifications have been effected. Some of the changes were prompted by wartime conditions; others were the result of operating experience with the Delray installation and a re-examination of piping design assumptions.

The 12-in. leads from the "near" and "far" steam generators are joined to the 14-in. turbine lead by the simple welded branch connection shown in Fig. 60. This simplification, over the specially constructed Y-fittings used at Delray, came about through inability to purchase the large cupped pipe required for making the Y-fittings.

It is obvious that the pressure drop through the side opening of the welded branch fitting will be greater than that through the "run" of the fitting. However, it is also true that the pressure drop from the "near" steam generator to the branch fitting is less than that from the "far" steam generator due to the shorter distance. Therefore, connecting the lead from the "near" unit to the side opening and the lead from the "far" unit to the "run" of the fitting tends to balance the pressure losses. In this respect the branch connection is an improvement over the Y-fitting and, in addition, it is considerably cheaper. The overall pressure drop from the superheater outlets to the turbine is estimated to be only about 1 psi greater than would be the case if a Y-fitting had been used.

Each of the 12-in. leads from the steam generators is connected to a 12-in. cross-over header as shown in Fig. 59. This header enables steam generators which normally function as part of a unit with a turbine to compensate for outage of any other steam generator. In addition, it provides a reliable source of steam for the emergency steam-driven boiler-feed pump and for the pressure-temperature reducing station.

Pressure Rating of Superheated Steam Valves and Design of Joints

With the exception of the connections to the pressure-temperature reducing station and to the steam-driven boiler-feed-pump turbine, all superheated steam valves are ASA 900-lb standard and have welding ends. Following the practice used at Delray, the bolted flanged joints were made to the 1500-lb standard to insure that such joints would remain tight on 865-psi, 910-F service with the expected line bending moments acting on the joints.

Flanged-end valves and welding-neck flanges have standard $^1/_4$-in. raised faces in accordance with ASA Standard B16e. Since it was not found necessary to seal-weld the modified Sargol joints which were used with metal gaskets at Delray, the extra cost of such facings did not seem to be justified for Marysville. Profile serrated monel gaskets are used. The gasket contact surfaces on flange faces were finished by grinding or lapping to a smooth surface. No spiral or radial scratches were permitted on the finished surfaces. The dimensions of the gaskets were proportioned to give a compression on the top of the serrations in excess of the bolt stress and a stress in the body of the gasket about one-half of the bolt stress. This procedure has proved satisfactory on a number of 910-F joints at Delray. For details of flanged joints on other piping systems at Marysville, see the accompanying table.

Small valves for bypasses, superheater inlet and outlet drips and the like, are ASA 1500-lb standard OS & Y, globe valves with Stellite No. 6 facing and socket-welding ends. With the exception of the $1^1/_4$-in. inside-screw globe valves on the superheater outlet drip connections, all such valves are of bonnetless construction.

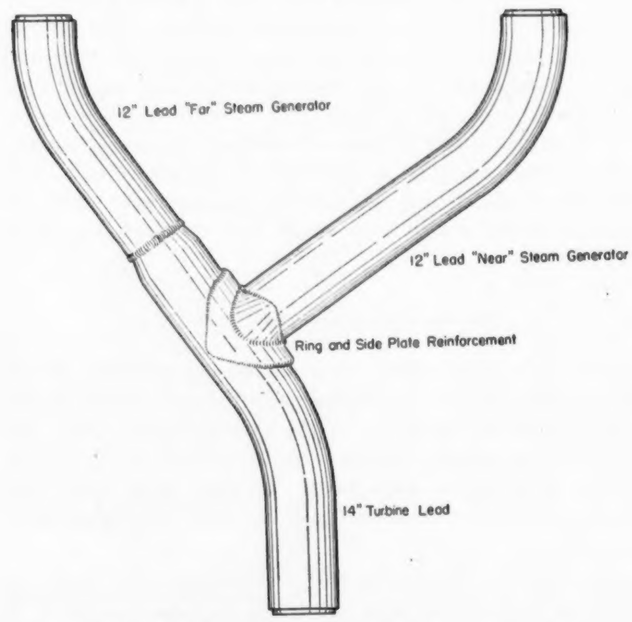


Fig. 60—Welded assembly joining leads from steam generators to the turbine lead

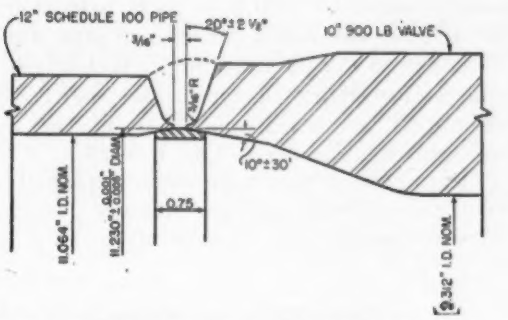


Fig. 61—Detail of pipe-to-valve welded joint for 10-in. 900-lb valve to 12-in. Schedule 100 pipe

"Venturi" Valves for Superheated Steam Piping

The use of 12-in. pipe and 10-in. parallel-slide gate valves for the steam generator leads agrees with the practice followed at Delray. Since the weight and cost of a 10-in. valve are approximately two-thirds the weight and cost of a 12-in. valve, and since the increase in pressure loss caused by the smaller valve is insignificant, the advantages of using the reduced size gate valves are apparent. The 12-in. pipe size was used to give better overall flow conditions and also better conditions for metering the steam.

At Delray the 12-in. steam generator leads were reduced to 10-in. at valve locations in order to make welded connections to the 10-in. valves. The cross-over header was also made of 10-in. pipe. At Marysville, the use of what might be termed "venturi" valves, that is, valves having welding ends machined to match pipe one size larger than the nominal valve size, made it feasible to use 12-in. pipe throughout the entire length of the steam generator leads and the cross-over header. It will be noted from the detail of the pipe-to-valve welded joint shown in Fig. 61 that the taper on the end of the valve, which is normally on the outside, has been placed on the inside of the valve in the "venturi" design.

In the ultimate plant, as now contemplated, the overall pressure drop from superheater outlets to turbine emergency stop valves, using "venturi" valves in the leads from the steam generators and in the header, will average about 40 psi for rated load on the turbines. This pressure drop compares with 50 psi allowed in design and with the 62 psi difference between the design turbine-throttle pressure of 815 psi and the 877 psi at which the lowest superheater safety valve closes. The use of 12-in. pipe in the cross-over header in place of 10-in. will enable full throttle steam pressure to be maintained at all turbines in the ultimate plant under rather adverse assumptions as to steam generator outage.

Welded Valve Bonnets for Superheated Steam Service

The proved reliability of welded-in seat rings with Stellite faces, which practically precludes the need for repairs, and the evident advantage of eliminating bolted flanged joints wherever possible on 910-F service, led to the adoption of the welded-bonnet valve design shown in Fig. 62 for installation in vertical lines. Where valves are installed in vertical lines, occasional leakage of bolted valve-bonnet joints has been experienced when the valves are in the closed position. Apparently, steam condenses in the body and the accumulation of water on the bottom half of the bonnet joint causes an unbalanced temperature condition which may result in leakage. While leakage of valve-bonnet joints at Delray seems to have been confined to the initial operation of the plant, the greater reliability of the welded-bonnet joint caused it to be selected for valves installed in vertical lines at Marysville.

Fabrication of Carbon-Moly Pipe

The Detroit Edison welding practice has been described rather fully in the technical press. Briefly, it involves use of the direct-current, metal-arc process, with the base material connected to the negative side of the line. Filler metal conforms to classification number E 6010 or E 7010 of the A.W.S.-A.S.T.M. Tentative Specification for Iron and Steel Arc Welding Electrodes, A.S.T.M. Specification A233. The welding procedure and the welding operators are qualified in accordance with the latest requirements of the ASA Code for Pressure Piping and Section IV of the A.S.M.E. Boiler Construction Code. The following special provisions for cleaning are included for high-pressure welding:

> "All slag or flux shall be removed from each crater by means of a light cleaning hammer before proceeding with the next electrode. Each completed bead or layer shall be thoroughly cleaned with a power-driven wire brush. It shall then be further prepared for deposition of the succeeding bead or layer by chipping out any defects such as cracks or blow holes that may appear, removing globules of spattered weld metal from the surface of the weld and the surface of the pipe ends, and generally correcting any condition which might prevent or interfere with the deposition of sound weld metal, adequately fused to the existing bead or layer and to the base metal. This cleaning

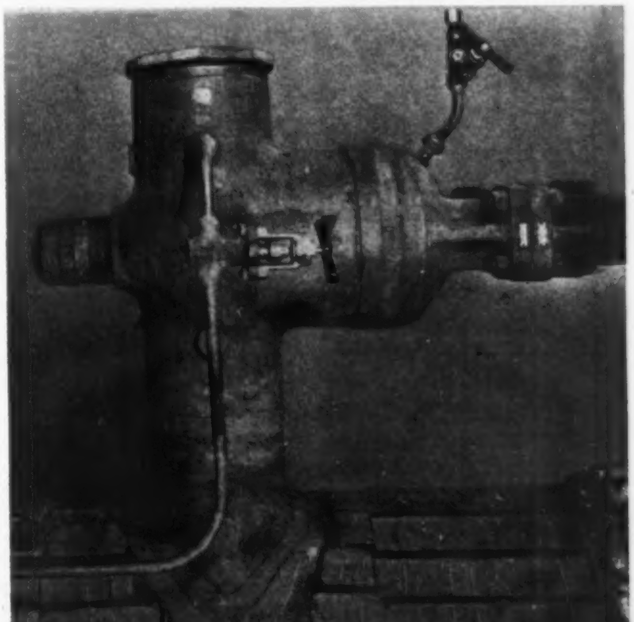


Fig. 62—Ten-inch, 900-lb welded-bonnet parallel-slide gate valve welded to 12-in. Schedule 100 pipe. Note ring-and-side-plate reinforcement on 12-in. branch connection and welded inspection cap on left side of valve body

shall be done by a chipper, assigned to the welder, using power-driven tools."

The type of welding bevel and backing ring adopted for Marysville high-pressure piping is shown in Fig. 61. Owing to wartime difficulties the piping fabricator was unable to machine bevel the 12-in. pipe ends. Accordingly, these ends were beveled by flame cutting and grinding, using a straight $37^{1}/_{2}$-deg bevel in place of the machined 20-deg U-bevel shown in Fig. 61. The continuous tapered backing ring was fitted in the pipe by grinding. A sample joint showed that it was possible for the Detroit Edison pipe fitters to prepare an entirely acceptable joint by this method. A qualification test weld made on a joint prepared by flame cutting and grinding demonstrated that no adverse effects were produced by this method of joint preparation.

Use of socket-type joints for couplings, fittings and valves in the smaller sizes was extended to include the $2^{1}/_{2}$- and 3-in. pipe sizes at Marysville, although butt-welded joints were used in these sizes as alternate construction. Welds in pipe lines, 2 in. and smaller, and those used in attaching bypass nipples to valve bodies, drains, instrument-source connections, and the like, were all of the socket type as at Delray.

Pipe-to-pipe and pipe-to-valve joints in the superheated steam lines were preheated to a temperature of 400 F to 600 F before welding. Electric resistance heating elements were clamped around the ends of the parts to be joined. The heating elements were covered with asbestos blankets both to facilitate heating the pipe and to shield the welding operators. The heating current was manually controlled and, in general, was left on during welding. An "Arcronograph" record of each bead of all important welds was obtained since experience at Conners Creek and Delray has demonstrated that such a record gives a reliable indication of uniform workmanship.

Post-heating, or stress-relieving, of groove welds in position was done with an electric induction heater. Welds were heated to 1200 F ± 25 F, held at temperature for at least two hours per inch of pipe wall thickness, and allowed to cool uniformly. Welded assemblies involving reinforced branch connections, such as shown in Figs. 60 and 62, were stress-relieved by heating the complete assembly in a furnace to 1200 F ± 25 F.

Superheated steam lines were given a hydrostatic test at twice the normal service pressure. Hydrostatic tests were witnessed by a representative of the insuring agency.

Boiler Feedwater Piping

A pictorial diagram of the boiler feedwater piping is reproduced in Fig. 63. This piping layout employs the same basic principles of boiler feedwater supply as were used in the Delray high-pressure section, except that boiler-water level is supervised directly by the fireman. The feedwater header is arranged as a ring so that it is possible to feed any boiler from either direction around the ring. A single riser is used to supply the ring header from the boiler-feed pumps. The arrangement for bypassing the two feedwater heaters on the discharge side of the boiler-feed pumps is shown in Fig. 63. The 8-in. line from the transfer pump which returns condensate from the low-pressure plant and the $2^{1}/_{2}$-in. line to the pressure-temperature reducing station are also shown in Fig. 63.

Each steam generator is connected to the ring header through a single line, although the method of providing a remote manual control of the bypass around the hydraulically operated feedwater regulator valve requires a second line for most of the distance between the ring header and the economizer inlet. The feedwater regulator valve and the manual bypass control valve were described in connection with the steam generators.

In addition to a boiler-water level indicator and recorder located on the main boiler control panel, means are provided whereby the fireman can see the water-column gage glasses on the boiler from his position on the operating floor. These means include lights which illuminate the water columns and the box-like shields shown in Fig. 64. Since the range of the gage glasses overlap in the normal water-level range, the fireman can see the meniscus in both gages when the water level is normal, but he sees only the meniscus in the upper or lower gage when the water level is above or below normal. With this arrangement, the boiler-water level is supervised directly by the fireman and no feedwater tenders are required. This represents a departure from previous Company practice.

Simple orifice plates are used at Marysville for measuring the feedwater instead of venturi tubes as were em-

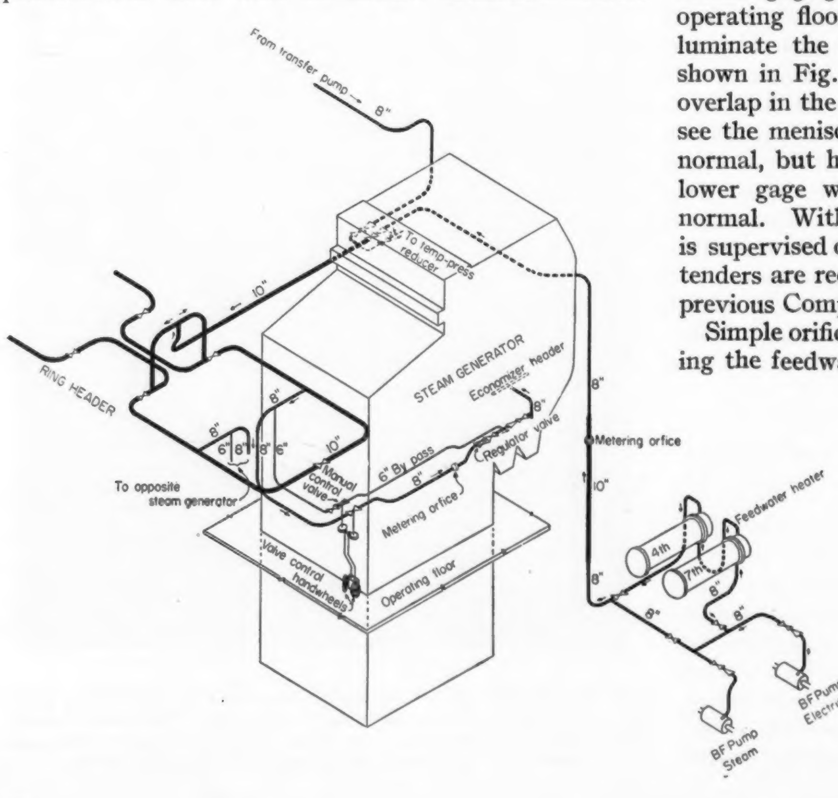


Fig. 63—Diagram of boiler feedwater piping

ployed at Delray. Orifice plates are installed in the riser from the boiler-feed pump and in the lines between the ring header and each economizer. The velocity in the 8-in. lines to the economizers for the maximum continuous load of 440,000 lb of steam per hour on the steam generator is 8 ft per sec. However, the velocity in the 8-in. riser from the boiler-feed pump for the maximum delivery from the pump is 11 ft per sec. In order to reduce this velocity for metering purposes, the section of the riser in which the orifice is located is increased to 10 in., as shown in Fig. 63.

Pressure Rating of Boiler-Feed Piping and Design of Joints

The piping from the economizer to and including the second stop valve was designed for 1220 psi, 540 F, as required by the Boiler Code for a boiler having its lowest drum safety valve set at 975 psi.

The piping from the boiler-feed pump to the second stop valve preceding the economizer was designed for the normal operating pressure and temperature condition of 1100 psi and 400 F.

Flanged connections to boiler-feed pumps, feedwater heaters, and to the feedwater regulator valve are ASA 900-lb standard with $^1/_4$-in. raised faces serrated for use with composition asbestos gaskets. For further details, reference may be made to the accompanying table, "Materials and Dimensional Standards for Piping."

Small valves for $^1/_2$- and $^3/_4$-in. bypasses on the 6- and 8-in. valves are 1500-lb OS & Y globe valves identical to those used in the superheated steam piping. Valves on the water-column piping are $1^1/_2$-in., 1500-lb wedge-gate type, with flanged ends and flanged bonnets (see tagged valve in Fig. 64).

"Venturi" Valves for Boiler-Feed Piping

The practice of using reduced-size valves which was described in connection with the superheated steam piping has been followed to some extent in the boiler-feed piping. Valves in the 10-in. ring header are 8-in. wedge-gate type with 10-in. welding ends.

Valve bonnets are flanged, since no difficulties have been experienced with flanged valve-bonnet joints on boiler feedwater service. Seat rings are welded in and seats and disk are faced with Stellite No. 6.

Fabrication of Boiler Feedwater Piping

Aside from the use of carbon-steel welding electrodes and the omission of preheating, the welding of boiler feedwater piping essentially conformed to that described for carbon-moly piping. The stress-relieving temperature was 1100 F to 1200 F in place of 1200 F ± 25 F, and the lines were given a hydrostatic test at $1^1/_2$ times the normal service pressure in place of two times. Hydrostatic tests were witnessed by a representative of the insuring agency.

First Year's Operation of the New Plant Equipment

The first of the new steam generators in the Marysville Plant was placed in service in September of 1942, and the second and third were available in January and September of 1943, respectively. The new turbine-generator, originally scheduled for operation in September 1942, was not available for service until the following April because of unforeseen delays encountered in manufacture.

Fortunately, the reducing station and other equipment provided for utilizing high-pressure steam in the low-pressure turbines was ready when the first steam generator was completed. It was thus possible for the operators to become thoroughly familiar with the behavior of the steam generators, mills and other auxiliary equipment without the necessity for maintaining a firm supply of high-pressure steam at the beginning. During this period minor changes and adjustments were made with more facility than would have been possible had steam been required by the new turbine-generator.

Thermal Performance

Curves showing the thermal efficiency and output of the plant for the last six months of 1942, and corresponding curves for the last six months of 1943 during which the new equipment was in service, are shown in Fig. 65. Factors entering into thermal efficiency, such as the quality of coal and condensing water temperature, were substantially the same for the two periods. Higher plant loads during 1943, however, made it possible to baseload the new unit so that it was possible during this latter period to take full advantage of the superior economy of that machine. Under these conditions the average heat rate of the plant during the last half of 1943 was 12,440 Btu per net kwhr whereas for the last half of 1942 it was 14,210 Btu per net kwhr.

Turbine-Room Operation

Operating experience with the new turbine-generator and associated equipment has been excellent. Only minor adjustments were necessary at the beginning and since then operation has become routine. This unit, the fourth in the series of identical 75,000-kw turbines installed by the Company, was not beset by troubles some-

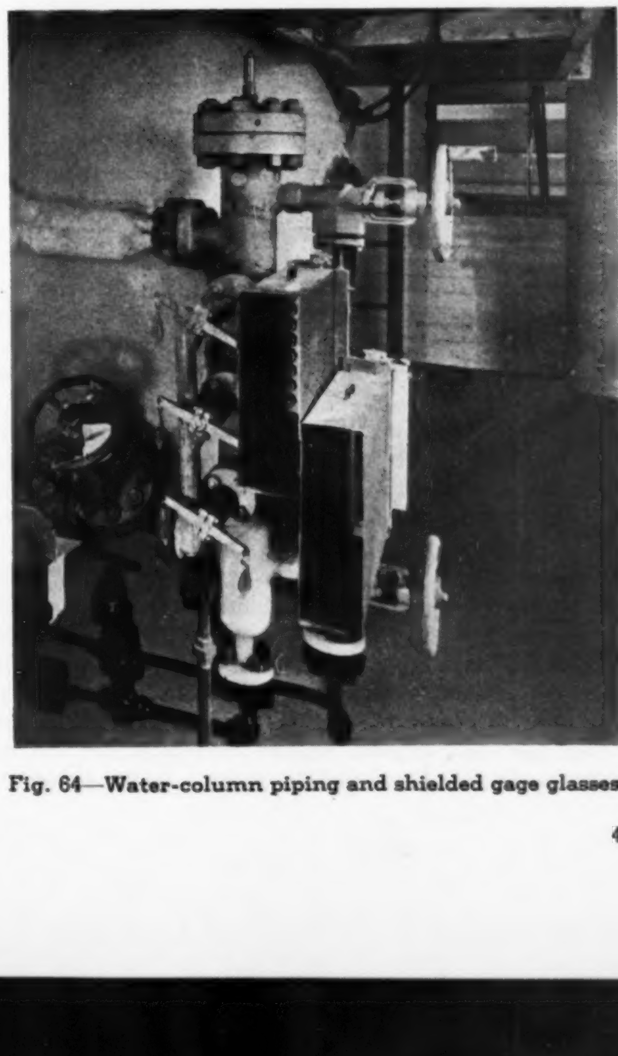


Fig. 64—Water-column piping and shielded gage glasses

times encountered in placing a turbine of a new design in service. Other than scheduled week-end shutdowns, the unit has been out of service only twice since it was started in April 1943. On the first of these occasions, in October 1943, the turbine and generator were balanced to remove slight vibration, several tube joints in the 4th- and 7th-stage heaters were repaired, and a steam-pressure governor control was installed. The second shutdown was made during January 1944 to repair a defective boiler-feed valve casting.

The purpose of the pressure-control device added to the turbine governor is to protect the turbine in the event of stoppage of coal in chutes, loss of pulverizing mills or any other trouble that would result in rapid loss of steam pressure. Its action is to reduce load on the unit in case the pressure tends to fall below 750 psi. In a recent trial of the device with a constant load on the unit the station pressure was slowly reduced. When pressure at the throttle reached 750 psi the control operated, dropping 10 mw of load from the machine which resulted in an increase in pressure at the throttle to 755 psi, all within 3 sec.

Heater and Evaporator Performance

Preliminary tests on the feedwater heaters associated with the new unit indicate that they are performing in accordance with specifications.

The use of city water to feed the new evaporator is a departure from past practice within the Company which has been to use untreated river water for this purpose. Although generally the use of river water has been satisfactory, in recent years at Conners Creek and also in the high-pressure section of Delray, coatings of oil and iron oxide have been found on the steam side of the condenser tubes and on the steam and water sides of the heater tubes. This deposit, which seems to be more pronounced on the water side of the low-temperature heater tubes, requires acid cleaning to restore proper performance.

Efforts to determine the source of the oil have not met with much success, presumably because of the small quantities entering the system. The accumulation over a period of years, however, is sufficient to cause the oil to adhere to the heat-exchange surfaces where it readily collects iron oxide and other impurities in the steam and condensate.

Believing that raw river water might be one possible source of oil contamination, it was decided to feed the new Marysville evaporator with city water which is filtered before entering the mains. Periodic inspections of the heat-exhange surfaces of the new equipment will be made for evidences of deposits such as those found at Delray and Conners Creek.

The scale formed in the evaporator by the city water appears to be about the same as that formed by the river water. Attempts to remove the scale by filling the shell with city water and then turning steam from the 7th-stage bleed point into the tubes has not been a wholly satisfactory means of removing all of the scale. Hence, the alternate method of first draining the shell, then putting steam through the tubes and finally filling the shell with cold water was tried. Using city water, this method was not completely effective because, due to the comparatively low water pressure, it was not possible to fill the shell rapidly enough to obtain the desired thermal shock. Provisions have been made, therefore, for the periodic use of river water from the high-pressure general service lines for the scale-cracking process. The removal of scale in this manner appears to be satisfactory and restores losses in capacity of from 2000 to 3000 lb per hr. The use of city water for evaporator feed will be continued.

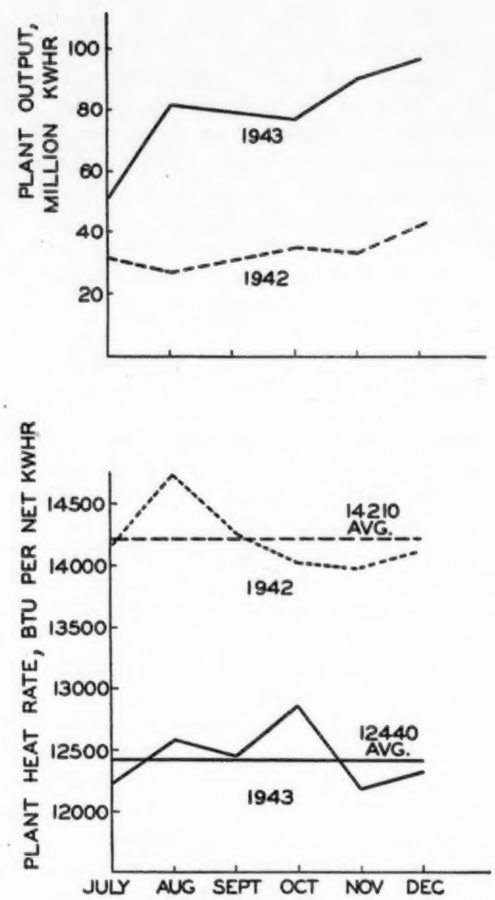


Fig. 65—Comparison of plant performance before and after addition of new high-pressure equipment

Boiler Feedwater Pressure Regulation

Pressure in the boiler feedwater header serving the new steam generators is controlled by manual adjustment of the boiler-feed pump speed. In normal operation, only the electrically driven boiler-feed pump installed with the new main unit is used and under this condition the control of header pressure is dependent entirely upon the speed of this pump.

The change from one point to another on the motor control causes a change of 60 to 70 psi in the boiler feed pressure. With a rapid change of this magnitude it is found that some change in the boiler-water level occurs before the level regulating valves can adjust themselves to the new pressure condition. Although this situation is not particularly bothersome, the control points will be rearranged to give a finer control in the normal pumping range. This will be accomplished by utilizing, in the higher range, some of the points now in the range below 200,000 lb per hr. With this modification the difference in header pressure corresponding to the change of one point on the controller in the normal pumping range will be of the order of 25 psi.

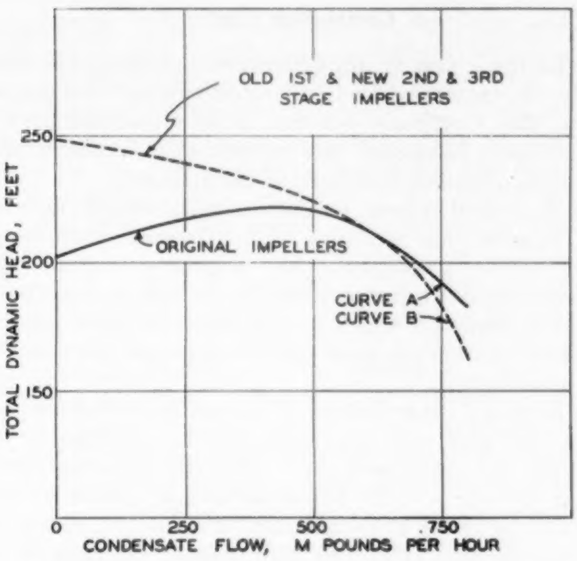


Fig. 66—Comparison of condenser pump characteristics with original and new impellers (870 rpm)

Combined Operation

As described previously, the utilization of steam from the new high-pressure steam generators in the old low-pressure turbines involves the return of condensate from the low-pressure 50,000-kw unit to the high-pressure boiler feed system. The return is accomplished by a combination heater-boiler feed pump, referred to as the transfer pump. It is a duplicate of the electrically driven combination heater-boiler feed pump associated with the new 75,000-kw main unit.

Condensate is pumped from the hotwell of the 50,000-kw unit by either of two duplicate condenser pumps which discharge through two stage heaters and thence through a line leading to the low-pressure boiler-feed storage tank system. The suction of the heater pump of the transfer set is connected directly into the latter line at a point ahead of the storage tanks. Thus when the transfer pump is in use it operates directly in series with the condenser pump. To insure adequate pressure to avoid flashing at the suction of the heater pump, constant pressure valves of the spring-loaded diaphragm type are installed in the condensate line.

It was found in the initial operation of the transfer pump that occasional severe water hammer occurred when the pressure at the discharge of the condenser pump dropped much below 50 psi. The action of the constant-pressure valves was first suspected as the cause of the pulsations but changes made to damp their action failed to improve the situation.

Further investigation showed that the cause of the trouble was most likely the "drooping head" characteristic of the condenser pump which is shown by Curve *A* of Fig. 66. From this it is seen that at delivery rates below about 500,000 lb per hr the characteristic is such as to give rise to instability and surging.

To correct this situation, new second- and third-stage impellers are being installed in the pumps which are expected to give the characteristic shown by Curve *B* of Fig. 66. In addition to eliminating water hammer, it is expected that the change will also improve the ability of the two condenser pumps to operate smoothly in parallel. This condition of operation might be required in the event of a sudden large demand for water by the high-pressure steam generators at a time when only the transfer pump is in operation; that is, at a time when the high-pressure main unit and its boiler-feed pump are shut down. In case this demand for feedwater should exceed the amount of condensate resulting from steam flow through the 50,000-kw turbine, additional condensate is drawn into the hotwell of the condenser from the condensate storage system.

Regulation of level in the low-pressure boiler-feed storage system was a manual operation before installation of the constant-pressure valves referred to above, the high- and low-level control valves on the hotwell of the 50,000-kw unit, and the level control valve on the low-pressure boiler-feed storage tank system—all of which were required for the proper control of condensate during combined operation. With the addition of these valves, the control of that level has now been made automatic at all times that the 50,000-kw unit is in operation, whether condensate is being returned to the high-pressure section or not.

During the past year, steam from the high-pressure section has been utilized for extended periods in the old low-pressure turbines because of outage of low-pressure boilers to permit major maintenance. It has been the practice to pass about 230,000 lb of steam per hour to the low-pressure system during the heavy day-load period and to lower the flow to about 60,000 lb per hr during the night and early morning hours. At the low flow, the transfer pump is shut down. Under this condition excess condensate in the low-pressure section is returned to the storage system by action of the high-level control valve at the hotwell of the 50,000-kw unit while the makeup condensate required in the high-pressure section is admitted from the storage system through the low-level control valve at the hotwell of the new 75,000-kw turbine.

Boiler-Room Operation and Steam Generator Cleaning

Operation of the new steam generators and other new equipment in the boiler room has in general been very satisfactory. Certain changes, however, have been or are in the process of being made to effect improved performance.

Present indications are that it will be possible to keep the new steam generators in service from one annual overhaul period to the next without outage for cleaning the heat-transfer surfaces. Experience has shown that the ash accumulation which builds up can be successfully removed by hand with steam lances. This ash accumulates on the furnace walls above the burning zone and between the burners and also on the furnace tubes which form the screen in front of the superheater. During continuous operation with all eight burners in service it is necessary to remove the accumulation by lancing twice a week. A drop to one mill and the use of only four burners at night causes considerable shedding of adherent ash and under this condition of operation it is necessary to hand lance only once a week.

The retractable soot blowers installed in the furnace roof, which were intended to clean the back wall screen and the front portion of the superheater immediately behind it, have not accomplished their purpose. Sub-

stitution of new type nozzles has not improved their performance. The velocity and direction of the combustion gases entering the tube bank tend to deflect the blower jets so that only a portion of the surface to be cleaned is touched by the steam. Although these blowers are still being operated weekly, thought is being given to discontinuing their use. The rotary soot blowers installed for cleaning the convection section of the superheater and the convection boiler surfaces have been effective and satisfactory in their operation. They are used once a day.

Examination of the economizer tubes which had been cleaned once a day with the fixed-position soot blowers showed them to be extremely clean after extended service. As a result, and in view of tests recently completed, the period between cleanings has been increased to two weeks. This frequency of use of the soot blowers appears to be sufficient due to the cleaning action of the ash in the flue gases.

Feedwater Conditioning

Satisfactory experience over a period of years with the high-pressure steam generators at both Conners Creek and Delray has shown the justification for internal boiler water treatment to prevent scale formation and corrosion. Accordingly, when the new Marysville steam generators were placed in service, they were also supplied with internal chemical treatment of the boiler water.

As had been the case in the other plants, examination of the Marysville steam generators after the first several months of operation showed deposits of black magnetic iron oxide in the drums. There was some concern over the fact that much larger amounts were found than had been expected. However, after cleaning and after extensive subsequent operation, examination of two of the units showed the interior surfaces to be in excellent condition with no evidence of loose oxide. It has been concluded, therefore, that the accumulation first found resulted largely from mill scale not thoroughly cleaned from some of the surfaces with which water and steam came in contact.

At Marysville the boiler water is treated initially inside the boiler with sufficient sodium phosphate salt and sodium hydroxide to insure a concentration of PO_4 and OH-ion in the water of about 40 ppm each. Thereafter, as weekly tests indicate the necessity, the concentration of these ions is readjusted, principally by the addition of either mono- or disodium phosphate. There usually is no need to add more sodium hydroxide. The limiting values for the concentration of these two ions are 10 and 40 ppm, minimum and maximum, respectively. No oxygen scavenger is used. The feedwater is normally oxygen-free and never contains over 0.01 ppm. Concentration of dissolved solids does not exceed 1000 ppm and averages about 300 ppm during prolonged operation.

The purity of the steam supplied by the new steam generators has shown the steam-washing equipment provided in the steam drums to be quite effective. Tests made on condensed steam samples representing total boiler water concentrations ranging from 100 to 850 ppm dissolved solids, show no difference in conductivity. An evaporation test of a sample representing the higher concentration gave a value of 0.51 ppm total dissolved solids.

Combustion Control

The three new steam generators are equipped with a fully automatic combustion control system—a departure from past Company practice in which adjustments of combustion conditions and regulation of steam pressure have been manual functions of the firemen.

The control system, which is compressed-air operated, is a combination of Bailey Meter Company and Hagan Corporation apparatus. As originally installed, the system did not function properly because one of the indices or variation which was intended to cause response of some of the individual control elements was found to be inadequate.

The initial control element is a station steam-pressure indicator and controller actuated by changes in the superheated steam pressure. Impulses from this master controller are transmitted to adjustable pressure relays or selector valves at each steam generator. These boiler master-pressure relays, in turn, supply impulses to the individual control elements which regulate the fuel feed and gas flow for their respective units.

In the original arrangement, the speed of the coal feeders, or the rate of fuel supply to the furnace, was governed as a function of the differential air pressure across the mill classifier. This index was applied to the primary air-flow controllers and to the mill-charge regulators. The action of the primary air-flow controllers was to increase or decrease the rate of pulverized coal flow from the mills according to the control pressure from the boiler-master-pressure relays. The action of the mill-charge regulators was to control the rate of coal feed to the mills according to the differential across the mill classifiers. This function of the mill-charge regulators was modified by an accelerating action that caused momentary over-speeding of the coal feeders on change of load, which speeded up the response of the pulverizer to a demand for change in output. The accelerating action was accomplished through the action of a solenoid which was energized by the mill motor current.

This fuel-feed control was designed on the basis that there would be a total range of differential air pressure across the mill of from 2 in. to 4 in. of water. In actual operation, this differential varied only from 1.6 in. to 2.7 in. of water. To secure a more positive control medium, the mill-charge regulators are now being operated on impulses from the boiler master-pressure relay. Several months of operation with this arrangement, which retains the accelerating action on pulverizer response, has shown the change to be satisfactory.

The induced-draft fan speed controller receives impulses from the boiler master-pressure relay as dictated by variation in steam pressure. It controls damper position, as a function of the total gas flow through the steam generator, measured by the pressure differential across a venturi section in the outlet gas duct. The damper-control drive mechanism is equipped with a mercoid switch device so that fan-motor speed will be automatically controlled to keep damper position within the effective dampering range.

The speed of the forced-draft fan was originally controlled in a similar manner except that the magnitude of change of speed was governed by the variation of furnace pressure. This arrangement caused considerable hunting of the fan control and was later modified by eliminating the connection from the boiler master-

pressure relay. The entire control of the forced-draft fan is now governed by the change in furnace pressure.

To maintain a proper ratio of fuel to air over the operating range of the steam generator, two means were provided in the original arrangement, both of which operated on the fuel control by modifying the control impulse to the primary air controllers. The first of these is the steam-flow air-flow meter, which maintains a constant excess air quantity over the operating range according to the calibration setting. The other means is the fuel-air ratio controller which also maintains a constant excess air quantity and compensates for changes in boiler cleanliness at the same time.

In actual operation, a steady steam pressure control condition was not obtained with this arrangement, because each time the fuel feed was altered to adjust the fuel-air ratio the steam pressure would be altered and this, in turn, would change the fuel feed again, setting up a hunting cycle. The steam-flow air-flow meter is now connected so that it modifies the induced-draft fan control impulse in order to obtain the fuel-air ratio desired. The hunting condition was thus overcome since the fuel-air ratio function is now maintained by modifying the air-flow control instead of the fuel feed. The fuel-air ratio controller is still connected so as to modify fuel feed, but is adjusted to a very low sensitivity which prevents any great effect on the fuel control impulse.

Provisions were made to hand control the induced- and forced-draft fans and fuel-feeder motors in the event of failure of the compressed air supply. The pressure relays installed at each steam generator are made adjustable so that, despite the fact that they all receive the same impulses from the station master regulator, the load may be proportioned between the steam generators as desired.

Steam Temperature Control

Experience with manual control of steam temperature through manipulation of the flue gas diversion damper and by tilting the burners has been satisfactory. Normal variation in steam temperature does not exceed ±10 F. Fig. 67 is a reproduction of a typical steam temperature chart. At steaming rates of 300,000 to 325,000 lb per hr the flue gas diversion damper is about two-fifths open.

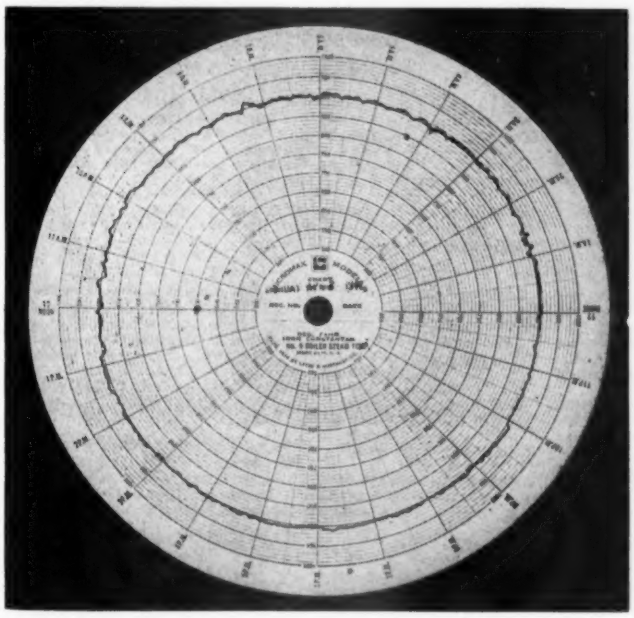


Fig. 67—Typical steam-temperature chart

Pulverizer Operation and Maintenance

The performance of the pulverizers has not been quite up to specification. Changes which have been made or are in the process of being made are expected to correct the shortcomings. Control of the mill air temperature to provide drying has been satisfactory. The temperature leaving the mills is maintained normally at 175 to 180 F. Coal containing as much as 9 per cent total moisture has been handled without trouble.

Difficulty, initially encountered with some of the mill rolls sticking during the starting period, has been eliminated by increasing the clearance between the roll bushings and the journal shafts. Operating and maintenance costs of the pulverizers have been about as expected for the type of coal being ground.

Coal and Ash Handling

Changes to the coal system, which involved the rearrangement and addition of conveyors to utilize the additional storage provided by the 2000-ton vertical bunker installed in the new addition to the boiler house, have worked out well in operation. It was found necessary to install grating over the track hoppers to prevent large pieces or frozen chunks of coal from getting into the conveyor system feeding the crushers. Trouble was encountered in handling wet coal, with plugging of one crusher. However, operation has been satisfactory since the coal feed was changed to the center of the crusher rather than at one end.

The character of the ash being collected in the furnace bottoms is entirely different than that for which the ash-settling pit was designed. Whereas it was thought that most of this ash would be clinkered, that collected is in a finely divided state with practically no slag or clinkers present. Handling of this ash in the sluices presents no difficulties. However, it is necessary to allow the ash to settle thoroughly in the ash pit and then to dewater the pit from the top, rather than from the bottom as originally planned, before the ash can be removed for disposal.

Handling of dry ash from the hoppers of the flue-dust collectors has presented no serious problems. The amount of air used to transport the ash from the plant to the storage silo has been reduced materially from the quantity at first thought necessary. The ash shut-off valves have also been improved to better control the thoroughly aerated or "wild" ash. Maintenance of the drag link conveyors which deliver the ash from the flue dust collector hoppers to the transport pump has not been excessive.

Conclusion

In this, the final installment of the series on the Marysville Plant, the recital of difficulties encountered in operation have been included in the belief that a discussion of such experiences would be of greater general interest than numerous statements on the many items in plant operation that have been successful. Where

troubles have occurred, the manufacturers involved have given excellent cooperation and are to be complimented for their help in correcting the difficulties.

General satisfaction with the design and operation of the new equipment is attested to by the fact that when additional capacity is required at Marysville it is planned to carry out the further rebuilding of the plant with equipment of essentially duplicate character.

MATERIALS AND DIMENSIONAL STANDARDS FOR PIPING

	Pipe Schedule and Specification Number	Style of Joint Nominal Sizes Used, In.			Flanges and Fittings Material and Pressure Standard			Valves Material and Pressure Standard		
		Screwed	Flanged	Welded	Screwed	Flanged	Welding	Screwed	Flanged	Welding
AIR, compressed	40–A120	3– [1]	4+	3– S[2] 2 1/2+ B	Malleable iron 150	Cast iron[6] 125	Steel S–Sch 40[3] B–Sch 40[4] 150[5]	Brass 125	Cast iron 125	....
BLOWOFF										
Boiler to last valve	80–A106	.....	3/4+	3– S	....	Steel 1500	Steel S–Sch 80 1500	...	....	....
Beyond last valve	80–A106	.....	2 1/2+	3– S 2 1/2+ B	....	Steel 600	Steel S–Sch 80 B–Sch 80 600	...	....	....
Evaporator	40–A135	2 and 3	4+	3– S 2 1/2+ B	Cast iron 125	Cast iron[6] 125	Steel S–Sch 40 B–Sch 40 150	Brass 125	Cast iron 125	....
CONDENSATE										
250-lb	40–A53[7]	1/2–2	2 1/2+	3– S 2 1/2+ B	Steel 3000	Cast iron 250 Steel 300	Steel S–Sch 40 B–Sch 40 300	Steel 300	Cast iron 250	....
100-lb	40–A53	1/2–2	2 1/2+	3– S 2 1/2+ B	Cast iron 125	Cast iron 125	Steel S–Sch 40 B–Sch 40 150	Brass 125	Cast iron 125	....
DRAIN, equipment	40–A120[8]	3–	4+	.....	Cast iron 125 Malleable iron 150	Cast iron[6] 125	Steel B–Sch 40 150	Brass 125	Cast iron 125	....
DRIP										
Superheated	160–A206	.....	2 1/2+	3– S 2 1/2+ B	....	...	Steel S–Sch 160[10] B–Sch 160 1500	...	Steel[11] 1500	Steel[11] 1500
975-lb saturated	80–A106[9]	.....	2 1/2+	3– S 2 1/2+ B	....	Steel 1500	Steel S–Sch 80 B–Sch 80 1500	...	Steel 1500	Steel 1500
300-lb saturated	Th–80[12] W–40 A53	1/2–2	2 1/2+	3– S 2 1/2+ B	....	...	Steel S–Sch 40 B–Sch 40 1/2–1 1/2 600 2 + 300	Steel 600	Steel 300	Steel 1/2–1 1/2 600 2 + 300
EXHAUST										
Turbine bleeder	40–A53[13] 12+, 3/8-in. wall	1/2–1 1/4[14]	2 1/2+	3– S 2 1/2+ B	....	Steel 600 300 150 Cast iron 125	Steel S–Sch 40 B–Sch 40	...	Steel 600 300 150 Cast iron 125	....
Auxiliary turbine	3/8-in. wall A135	.....	12	12 B	....	Steel 150	Steel fabricated from plate and pipe	...	....	....
FEEDWATER										
Connections to boiler	3/4–4 Sch 80[15] 6–Sch 120 8–Sch 100	.....	2 1/2+	3– S 2 1/2+ B	3–8 1/2–2 1/2	Alloy[16] 900 Steel 1500	Steel S–Sch 80 2 1/2–4 B–Sch 80 6"B–Sch 120 8"B–Sch 100 Alloy 900	...	3–8 1/2–2 1/2	Alloy[16] 900 Steel 1500
System	80–A106	.....	2 1/2+	3– S 2 1/2+ B	....	Steel 900	Steel S–Sch 80 B–Sch 80 900	...	....	Steel S–Sch 80 B–Sch 80 900
INSTRUMENT										
High-pressure	160–A206 80–A106	.....	3/4+	3– S	....	...	Steel S–Sch 80 1500	Steel[17] 3000	Steel 1500	....
Low-pressure	40–A120[18]	3– (flared)	4+	3– S	Steel 3000	Cast iron[6] 125	Steel S–Sch 40 150	Brass 125	....	....
OIL										
Turbine lubricating	40–A53	.....	3/4+	3– S 4+ B	....	Steel 150 Cast iron 125	Steel[19, 20] S–Sch 40 150 400 600	...	Steel 150	Steel 150
Transformer	40–A120	3–	4+	3– S 2 1/2+ B	Cast iron 125	Cast iron[6] 125	Steel 150	Brass 125	Cast iron 125	....
WATER										
City and general service inside	40–A120[21]	3–	4+	3– S 2 1/2+ B	Malleable iron 150 galvanized	Cast iron[6] 125	Steel S–Sch 40 B–Sch 40 150	Brass 125	Cast iron 125	Steel 150
City and general service outside	40–A120[22]	3–	4+	3– S 2 1/2+ B	Malleable iron 150 galvanized	Cast iron[6] 125	Steel S–Sch 40 B–Sch 40 150	Brass 125	Cast iron 125	Steel 150
STEAM										
Main and auxiliary superheated	3/4–3 160–A206 4 and 6 120–A206 8+ 100–A206	.....	2 1/2+	3– S 2 1/2+ B	....	Alloy[23] 1500	Alloy[23] S–Sch 160[24] 1500	...	Alloy[23] 1500	Alloy[23] 900
975-lb saturated	80–A106[9]	.....	2 1/2+	3– S 2 1/2+ B	....	Steel 1/2–2 1/2 1500 3 + 900	Steel S–Sch 80[10] B–Sch 80[10] 1/2–2 1/2 1500 3 + 900[25]	...	Steel 1/2–2 1/2 1500 3 + 900	Steel 1/2–2 1/2 1500 3 + 900

300-lb saturated	40–A53	.....	$2^1/_2$+	3– S $2^1/_2$+ B	....	Steel 300	Steel S–Sch 40 B–Sch 40 $^1/_2$–$1^1/_2$ 600 2 + 300	Steel 600	Steel $^1/_2$–$1^1/_2$ 600 2 + 300	Steel $^1/_2$–$1^1/_2$ 600 2 + 300
VACUUM	40–A135 –A120	3–	4+	3– S $2^1/_2$+ B	Cast iron 125	Cast iron 125 Steel 150	Steel S–Sch 40 B–Sch 40	Brass 125	Cast iron 125 Steel 150	Steel 150
VENT										
Safety valve	40–A120 –A135	3–	4+	3– S $2^1/_2$+ B	Cast iron 125 Steel 3000	Cast iron[6] 125 Steel 150	Steel S–Sch 40 B–Sch 40 1500[26]	Brass 125	Cast iron 125	....
Hotwell pump	Copper									

Gaskets.—Red rubber in joints up to 250 F, asbestos composition up to 800 F, profile serrated Monel for 910 F.
Joint Facings.—ASA Std. raised faces, serrated for asbestos gaskets, ground face for Monel gaskets.
Bolting—Cast-iron flanges; square or hexagonal head machine bolts with heavy hexagonal nuts. Steel flanges for services up to 800 lb 750 F; bolt studs A.S.T.M. A96 Class A, services up to 1200 lb, 750 F, A.S.T.M. A96 Class C, for temperature of 910 F; A.S.T.M. A193 Grade B14 bolt studs with nuts to A.S.T.M. A194 Class 2H.

NOTES FOR TABLE

[1] 3– is used to indicate sizes 3 in. and smaller; 4+, 4 in. and larger, etc.
[2] S indicates socket-welded; B, butt-welded.
[3] S–Sch 40 refers to Schedule 40 fittings of the proposed Amer. Std. for Steel socket-welding fittings, ASA B16.11.
[4] B–Sch 40 refers to Schedule 40 fittings of the Amer. Std. for Steel butt-welding fittings, ASA B16.9.
[5] 150, 1500, 600, etc., indicate standard of welding-neck flanges, ASA B16e.
[6] Screwed cast-iron companion flanges may be used in these services.
[7] Seamless A53 or electric-resistance welded A135 also suitable.
[8] Also A135, copper Class L with soldered connections extra-heavy cast-iron soil pipe and Class A water pipe.
[9] Also seamless A53.
[10] Carbon steel WF, A234.
[11] Cast or forged carbon steel adequate because of intermittent operation and low average temperature of drip lines.
[12] Th = threaded, W = welded seamless A53 or A106.
[13] Seamless low or medium carbon A53, or A106 for two high-pressure bleed lines, electric resistance welded A135 for lower pressure lines.
[14] Threaded nipples for highest pressure line—double extra strong, lower pressure lines $^1/_2$ to $^3/_4$ in.; Schedule 80, 1 and $1^1/_4$; Schedule 40.
[15] Thicknesses of seamless Grade B A106 pipe required to meet Boiler Code requirements for 975-lb boiler drum pressure.
[16] Carbon-molybdenum alloy steel required by Boiler Code to permit use of 900-lb standard valves.
[17] Screwed 3000-lb valves remote from source.
[18] Also copper tubing and thin-walled steel tubing with flared-tube connections or soldered copper connections.
[19] Connections to turbine $^1/_4$ to 3 in. 600-lb, 4 in. and larger 400-lb with large male-female facing.
[20] Welding-neck flanges for connection to cast-iron pump and oil strainer flanges have raised faces omitted, except in the 3; 6- and 8-in. sizes.
[21] Sizes $^1/_2$ to 3 in. galvanized, 4 to 10 black. 12 in. and larger, $^3/_8$-in. wall.
[22] Also Class C cast-iron bell-and-spigot joints; lead (extra-strong quality) for city water; and copper Class K.
[23] Chrome-nickel-moly Grade WC 4, A217, or carbon-moly Grade WC 1, A217.
[24] Carbon-moly Grade $WF1_1$, A234.
[25] Except terminating flanges on connections to boiler drum which are 1500-lb.
[26] Vent from economizer relief valve; 1500-lb flanges and valve.

Tabulation of Principal Equipment Data

NEW SECTION OF MARYSVILLE POWER HOUSE

Main Turbine

75,000 kw, 815 psi gage, 900 F, 1800 rpm; 1 two-row Curtis and 16 single-row stages; steam extracted at fourth, seventh, tenth and thirteenth stages.—*General Electric Company*

Main Generator

100,000 kva at 0.75 power factor, 14,400 volts, four-pole, 60-cycle, three-phase. Exciter, direct-connected, 250 kw, 250 volts.—*General Electric Company*

Generator Air Cooler

One 2-pass, 14,400 sq ft arsenical-copper finned tubes, 1-in. OD, No. 18 gage; total air flow, 130,000 cfm.—*General Electric Company*

Main Condenser

47,800-sq ft, single-pass, 10,252 tubes, 24-ft long, $^7/_8$-in. OD, No. 18 gage.—*Worthington Pump and Machinery Corporation*

Main Circulator Pump

One per condenser, 48-in. horizontal, double suction, split-case volute pump; capacity, 70,000 gpm against a total dynamic operating head of 13 ft at a speed of 240 rpm. *General Electric* d-c motor, 240 volts, 350/116 hp at 240/166 rpm.—*Worthington Pump and Machinery Corporation*

Chlorination Equipment

Capacity to treat a maximum flow of 475,000 gpm of condensing water at a maximum dose of 1.05 ppm. The chlorinator has an operating range of 7 to 1. Maximum capacity in terms of chlorine flow, 6000 lb per 24 hr. Liquid chlorine is purchased in one-ton containers. Chlorine evaporator is provided with an electrically heated water bath with thermostat temperature control. Heater capacity is 12,000 watts.

The chlorine solution is introduced periodically into plant main condensing water intake. Program control varies for treatment range varying from once in $1^1/_2$ hr to once in 24 hr. Maximum length of each chlorination period is 80 min.—*Wallace & Tiernan Company, Inc.*

Vacuum Pump

One horizontal rotating reciprocating-type pump, single-cylinder, two-stage, 39 in. by 30 in., 2050 cfm displacement at 100 rpm. *General Electric* d-c motor, 230 volts, 40/12 hp, 100/30 rpm.—*Laidlaw-Dunn-Gordon*

(Pump was formerly installed at Delray Power Plant.)

Oil Coolers

Duplicate vertical type.—*Schutte & Koerting Company*

Main Generator Ventilating Fans

Four external fans per generator.

Each driven by direct-connected induction motor, 220 volts, 100 hp, 1175 rpm. Three fan motors connected electrically through transformer to generator terminals. Fourth fan motor supplied from 230-volt, a-c house service bus.

Generator Transformer

100,000-kva, OIWC, 14.4/26 kv, three-phase, auto-transformer.—*General Electric Company*

Cable Feed

Nine 350M-cir mil, three-conductor, 24 kv, paper and lead cables.

Generator Breaker

Type GO4A, 3000 amp, 34.5 kv, 1.5 million kva interrupting capacity, solenoid operated.—*Westinghouse Electric & Manufacturing Company*

Tie Transformers

Constitute interconnection between 24-kv and 120-kv buses.

Two 15,000-kva banks of single-phase OIWC units in parallel, and one 30,000-kva, three-phase OIWC unit; 120/24-kv nominal ratio with ±10% ratio control under load.

STEAM GENERATORS

Boilers

Three-drum, natural circulation, bent-tube with integral superheater and economizer. Drum diameters, upper rear 60 in., upper front 48 in., lower drum 36 in. Drum lengths overall and including heads, 30 ft 3 in., 29 ft 9 in., and 26 ft 9 in., respectively. Maximum working steam pressure, 975 psi gage, 440,000 lb per hr. Total effective heating surface, 6575 sq ft; tubes, 3 in. OD.—*Combustion Engineering Company, Inc.*

Water Walls

Roof tubes finned. Bifurcated plain tubes for front, rear and side walls, and plain tubes for furnace-bottom screen. Total effective heating surface of furnace tubes, 7098 sq ft. All tubes 3 in. OD, except for $3^1/_2$-in. OD internal down-take tubes. Furnace volume, 27,830 cu ft, width 23 ft 11 in.; 21 ft 4 in. front to rear.—*Combustion Engineering Company, Inc.*

Superheaters

Elesco, two-section, interbank; total effective heating surface, 15,982 sq ft; 910 F ± 10 deg F at 865 psi from 225,000 lb per hr to 480,000 lb per hr with feedwater entering economizer at 375 F. Flue-gas bypass damper for temperature regulation.—*Combustion Engineering Company, Inc.*

Economizers

Elesco finned-tube, horizontal; total effective heating surface, 12,136 sq ft. Tubes 2 in. OD, No. 7 gage. One $10^3/_4$-in. OD inlet header and one $8^5/_8$-in. OD outlet header.—*Combustion Engineering Company, Inc.*

Air Heaters

Two per steam generator.

Ljungstrom No. 19-CGZX regenerative-type, vertical gas-air flow. Element height 56 in. in two sections of 42 in. and 14 in.

Material in elements: 42-in. section, No. 24 U. S. gage O.H. steel; 14-in. section, No. 24 U. S. gage Toncan Iron. Heating surface, each of two heaters, 41,800 sq. ft. Each heater is driven by one 5-hp, 240-volt, d-c constant-speed motor.—*The Air Preheater Corporation*

Forced-Draft Fans

Two per steam generator.

No. 10, single-width, double inlet, 69,000 cfm, 70 F, 12.6 in. of water, 995 rpm; one motor for both fans, 230 volt, d-c, 400 hp at 1000 rpm, 50 hp at 500 rpm. Field regulation, 1000 to 500 rpm; armature regulation, 500 to 250 rpm.—*American Blower Corporation*

Induced-Draft Fans

One per steam generator.

No. $11^1/_4$, $^3/_4$-D.W. Sirocco, 249,200 cfm, 331 F, 15.47 in. of water, 639 rpm. One motor, 230-volt, d-c, 900 hp at 700 rpm; 92 hp at 300 rpm. Field regula-

tion, 700 to 300 rpm; armature regulation, 300 to 240 rpm.—*American Blower Corporation*

Soot Blowers

Revolving blowers for convection tube surface of superheater and boiler and retractable-oscillating blowers for radiant section of superheater by the *Diamond Power Specialty Corporation*. Fixed integral-type blowers for economizer tubes by *The Detroit Edison Company*

Water Columns

Water columns and bi-color illuminators by *Diamond Power Specialty Corporation*

Stacks

Two steam generators per stack, self-supporting, steel fabricated by *Muskegon Boiler Works*. Erected by *The Detroit Edison Company*

Flue-Dust Collectors

One per steam generator; electrostatic type with perforated steel plate electrodes. Two units, 17 ducts each in width, by 3 sections in length. Plates 17 ft 6 in. high set on $8^3/_4$-in. centers. Motor-operated plate rappers. Primary power supply, three-phase, 230 volts. Two half-wave rectifiers.—*Research Corporation*

FUEL PULVERIZING AND BURNING EQUIPMENT

Pulverizers

Two per steam generator, Raymond No. 573 bowl-type with integral exhauster fan. Nominal capacity, 24,100 lb per hr based on coal with 50 Hardgrove grindability, 10 per cent moisture. Fineness, 70 per cent through 200-mesh sieve. Pulverizer and fan driven by one 250-hp, 440-volt, constant-speed, 1200-rpm motor.

Pulverizer Feeders

One per pulverizer driven by 1-hp, 240-volt, d-c, 1800-rpm, shunt-wound motor, 4-to-1 speed adjustment.

Burners

Tangentially fired, eight per furnace, size 10 in. Fuel pipes 24 in. diameter before and 10 in. diameter after division into branch lines to burner. Riffle distribution fitting used at each division.

Two burners at each corner of furnace installed with dampered casing for admission of secondary air. Six air compartments.

Burner casings equipped with gas ignition torches. Gas lighted with spark-type igniter.

Combustion Engineering Company, Inc.

FEEDWATER HEATERS

High-Pressure

Four-pass, horizontal, closed-type with de-superheating zone, lock-head floating head, 1200 psi gage pressure, $^5/_8$-in. OD, 16-gage tubes. Tube material, cupro nickel. (Fourth- and seventh-stage heaters.)

Low-Pressure

Four-pass, horizontal, closed-type, floating head, 250 psi gage pressure, $^5/_8$ in. OD, 18-gage tubes. Tube material, Admiralty metal. (Tenth- and thirteenth-stage heaters.)

Drains Heat Exchanger

Two-pass, vertical closed-type, floating head, 250 psi gage pressure, $^5/_8$-in., 18-gage tubes. Tube material, Admiralty metal.

Heating Surface

Fourth-stage, 3575 sq ft; seventh-stage, 3090 sq ft; tenth-stage, 2730 sq ft; thirteenth-stage, 2760 sq ft. Drains heat exchanger, 477 sq ft.

All by *Foster-Wheeler Corporation*

Evaporator

Style R, bent-tube, horizontal submerged type, size 102-A-130, 244 sq ft heating surface. 1-in. OD, 16-gage tubes; capacity, 10,300 lb per hr. Shell, 54-in. OD, full-welded steel construction. 46 sq ft of disengaging surface.—*Griscom-Russell Company*

PUMPS

Boiler-feed and heater pumps, two per main unit.

Heater pump, two-stage, 1370 gpm, 223 psi discharge pressure, 28 psi suction pressure, 1770 rpm, water temperature 100 F.

Boiler-feed pump, seven-stage, 1455 gpm, 1200 psi discharge pressure, 183 psi suction pressure, 1770 rpm, water temperature 260 F.

De Laval Steam Turbine Company

Drive

Motor-driven set; *General Electric Company*, 4800-volt, slip-ring motor, 1500 hp at 1785 rpm.

NOTE: The motor-driven transfer pump is a duplicate of this pump.

Turbine-driven set; *De Laval* steam turbine, 1438 hp, 1770 rpm. Steam supply, 815 psi gage, 900 F. Arranged for normal exhaust to main unit condenser but with alternate exhaust to atmosphere.

Condenser Pumps

One single-stage, double-suction, horizontal split case, *De Laval* pump, having a manufacturer's rating of 1570 gpm at 870 rpm against 30 psi gage discharge pressure with water delivered to the pump suction at a net positive suction head of 3 ft. (Net pressure 100 ft, including suction lift.) Driven by an adjustable speed, 230-volt, d-c, 75-hp motor, 870 rpm.

One vertical-shaft, *Byron Jackson* pump, 1560 gpm, 30 psi gage discharge, 875 rpm. Motor, vertical-shaft, constant-speed, 75-hp, 220-volt, a-c.

Heater Drains Pump

One *De Laval* horizontal, split-case pump, 287 gpm, 210 to 216 psi gage discharge pressure, 20 to 26 psi gage suction pressure; water temperature 258 F. Driven by one constant-speed, 60-hp, 1760-rpm, 220-volt, a-c motor.

PIPING AND VALVES

Pipe and Pipe Fabrication

National Tube Company
M. W. Kellogg Company
Murray W. Sales Company
The Detroit Edison Company

High-Pressure Superheated Steam Valves

Parallel slide gate valves.—*Lunkenheimer Company*
Valve motor operators.—*Cutler-Hammer Company*
Stop and check valves.—*Schutte & Koerting Company*

High-Pressure Saturated Steam and Boiler Feedwater Valves

Wedge-gate valves.—*Lunkenheimer Company*
Globe valves.—*Republic Flow Meters Company*
Check valves, piston type.—*Lunkenheimer Company*

Feedwater Regulators

One per steam generator, 6-in. "*Copes* Flowmatic," steam-flow water-level actuation, hydraulically operated.—*Northern Equipment Company*

Safety Valves

Three 4-in. pop safety valves per boiler, average capacity 132,700 lb per hr of saturated steam. Two $2^1/_2$-in. safety valves per superheater, average capacity 61,500 lb per hr of superheated steam.—*Crosby Steam Gage and Valve Company*

Blow-off Valves

Two $1^1/_2$-in. per steam generator (lower drum).—*Lunkenheimer Company*
Two $1^1/_2$-in. per steam generator (rear water-wall header).—*Consolidated Ashcroft Hancock Company, Inc.*

Miscellaneous Small High-Pressure Valves for Drains, Bypasses, Instruments, Etc.

Globe valves.—*Lunkenheimer Company*

Main Superheated Steam, Pressure-Temperature Reducing Station

Republic Flow Meters Company (*Smoot*). Two units, both with automatic de-superheating control but only one with automatic pressure control. Units of equal capacity, each 279,000 lb per hr with initial pressure 825 to 875 psi, initial temperature 900 to 925 F. Final pressure 275 to 300 psi, temperature 700 to 725 F.

Taylor Instrument Company fulscope pressure-temperature controller.

INSTRUMENTS

Indicating and Recording Temperature

C. J. Tagliabue Company
Bristol Company
Consolidated Ashcroft Hancock Company, Inc.
General Electric Company
Leeds & Northrup Company
Taylor Instrument Company
Bailey Meter Company

Combustion Meters

Steam Flow-Air Flow.—*Bailey Meter Company*

Flow Meters

Mechanical-type meters.—*Bailey Meter Company*

Water Level

Low-pressure gage glasses.—*Crane Company*
Remote-level indication.—*The Liquidometer Corporation*
Boiler water-level indicators.—*Diamond Power Specialty Corporation*
Boiler water-level recorders.—*Republic Flow Meters Company*

Pulverizer Feeder Tachometers

Electrical indicating type.—*The Electric Tachometer Corporation*

Turbine Supervisory Control

Elinco Signal System.—*Electric Indicator Corporation*

Two pressure-governor switches.—*General Electric Company*

(One starts motor-driven auxiliary oil pump in case of low oil pressure. The other starts synchronizing motor in direction to unload turbine-generator in case of low steam pressure.)

Indicating tachometer.—*General Electric Company*

Combined, speed, camshaft-position recorder. Manual selector switch. With generator synchronized, the camshaft position record is a measure of valve opening and consequently load on the turbine.—*General Electric Company*

Condensate

Oxygen recorder.—*Cambridge Instrument Company*
Conductivity alarm.—*Industrial Instruments, Inc.*

COAL HANDLING

Drag-Line Scraper

220 tons per hour.—*Sauerman Bros., Inc.*

Coal Crushers

Three No. 7 Williams Jumbo, 200 tons per hour.—*Williams Patent Crusher & Pulverizer Company*

Conveyors

Link-Belt Company
Robins Conveyers, Inc.

Coal Unloading Dock

The Detroit Edison Company

ASH HANDLING

Flue Dust

Flue-dust collector drag conveyors (Redler).—*Stephens Adamson Company*
Flue-dust transport pumps (Fuller Kinyon type).—*The Fuller Company*
Rotary air compressor.—*The Fuller Company*
Flue-dust dampner, unloader.—*United Conveyor Company*
Flue-dust filters.—*Dracco Corporation*

Furnace-Bottom Ash

Furnace hopper ash gates.—*Allen-Sherman-Hoff Company*
Water sluice system.—*Allen-Sherman-Hoff Company*
Sluice, pumps, sludge pump, dewatering pump and sealing water pumps.—*Allen-Sherman-Hoff Company*
Ash separation sump.—*Allen-Sherman-Hoff Company* and *The Detroit Edison Company*

Fuel Conservation Program Aims to Save 29 Million Tons of Fuel

THAT we were able to get through the last heating season without undue hardship and curtailed production, despite considerable loss in coal output because of strikes, was attributable largely to the very substantial stocks in storage at the beginning of 1943, as well as to reallocations of coal to certain areas. However, the present year started off with an average of about 40 per cent less coal in storage, an estimated increase in consumption and little promise of increased coal production, due to the many miners that had either been inducted into the services or gone to work in war plants. The net result, assuming a rate of output equal to the last months of 1943, is a threatened shortage variously estimated at from 25 to 29 million tons—approximately four-fifths bituminous and one-fifth anthracite.

Faced with this situation, a National Fuel Efficiency Program is being put into effect. This is administered by a Council of twelve recognized authorities in fuel utilization, with the cooperation of the U. S. Bureau of Mines, and functioning through Regional Coordinators, covering all sections of the country. These Coordinators will select and be assisted by hundreds of engineers who will contact fuel-burning plants, secure the cooperation of the managements, make surveys and distribute helpful information toward effecting possible savings. Moreover, in each plant an individual will be designated as a "Waste Chaser," who will be charged with the responsibility of conserving fuel by various means and who will be assisted to this end by the contact engineer in his locality. All are giving their services voluntarily as a patriotic duty and personnel are being carefully selected as to practical experience.

The setup is similar in many respects to the plan that has been operative in England for a considerable period with excellent results.

At the start, the program encompasses only industrial power plants (including railroad roundhouses), large and small heating plants (including apartment houses but not residential heating), and industrial furnaces; also boilers in such plants burning gas or oil, as there is urgent need for conservation of these fuels. This decision is believed to have been based on the assumption that such plants, to a greater extent than many of the large power plants, are most susceptible to elimination of waste through improvement in fuel-burning practice and that the resulting aggregate savings should be substantial. It is also expected that very large savings can be made outside the boiler plant; that is, in the application and utilization of both steam and heat.

The Council, under whose direction the program is being carried out, is composed of Thomas C. Cheasley, Fuel Engineer, Sinclair Coal Co., Chairman; O. F. Campbell, Combustion Engineer, Sinclair Refining Company; W. G. Christy, Smoke Abatement Engineer, Hudson County, N. J.; C. F. Hardy, Appalachian Coals, Inc.; H. K. Kugel, Smoke Regulation Engineer, District of Columbia; L. S. Reagan, V. P. Webster Engineering Co.; C. A. Reed, Dir. of Engrg., National Coal Association; H. J. Rose, V. P. in Charge of Research, Anthracite Industries, Inc.; R. A. Sherman, Supervisor, Fuels Div., Battelle Memorial Inst.; A. W. Thorson, Head Conservation Engineer, Solid Fuels Administration; J. E. Tobey, Managing Director, Coal Bureau, Upper Monongahela Valley Association; and J. F. Barkley, Chief, Division of Solid Fuels, U. S. Bureau of Mines.

Various forms have been prepared for surveying plants and compiling information as well as others containing practical instructions for assisting the "Waste Chaser." In addition to the name and address of the plant, the pledge official and the "Waste Chaser," space is provided for full information on the boilers, and auxiliaries, fuel, method of firing, combustion conditions and control, loading, utilization of exhaust, insulation, steam distribustion and apparent wastes, recommendations for effecting savings and an estimate of the fuel savings possible. In the case of heating plants, additional information is called for on building dimensions, amount of radiation, piping installation, adequacy of air vents, method of heating hot water and emission of smoke.

Check sheets have already been prepared dealing with stoker-fired plants burning up to 1200 lb of bituminous coal per hour and others cover the burning of bituminous coal on hand-fired grates, the burning anthracite on underfeed stokers under boilers up to 300 hp; hand-firing of anthracite for medium-size and large heating boilers; small and medium-size boilers burning gas and those burning light or heavy fuel oil. Additional quiz sheets are now being prepared covering all phases of steam generation and heat utilization from coal handling through time-chart heating control.

These quiz sheets have been prepared through the helpful cooperation of various associations in the field and are thus based on wide experience.

Among the literature recommended for reading are the following:

1. "Questions and Answers for the Coal Fireman" by J. F. Barkley, U. S. Bureau of Mines Handbook (1941); obtainable free of charge from the Office of Mineral Reports, U. S. Bureau of Mines, Washington, D. C.
2. "Firing a Hand-Fired Down-Draft Furnace" by J. F. Barkley, U. S. Bureau of Mines Paper 2609; obtainable from the above source.
3. "Hand-Firing Soft Coal Under Power Plant Boilers" by Henry Kreisinger, U. S. Bureau of Mines Technical Paper 80; obtainable from Supt. of Documents, Government Printing Office, Washington, D. C.; price 10 cents.

The whole program represents a vast undertaking, requiring the patriotic cooperation of many bodies and individuals, as well as owners and plant managements. This involves building up the organization, carrying out the field work, and making provision for analyzing and consolidating the information obtained. At present the organizing work is well along and many of the quiz sheets have been prepared; the actual field work is soon to follow. As the work proceeds information as to progress will become available.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

A.S.T.M. Specifications for Steel Piping Materials

American Society for Testing Materials

The 1943 edition of this compilation of all specifications issued by the A.S.T.M. covering steel piping materials includes 44 standards and provides 25 emergency alternate provisions that have been issued to aid in expediting procurement. Many of the specifications and emergency provisions are part of schedules appended to WPB limitation order L211.

This 255-page publication, size 6 × 9, can be obtained in heavy paper cover at $1.75 per copy.

Fundamentals of Coal Sampling

(Bureau of Mines Bulletin No. 454)

By Bertrand A. Landry

This recent Bulletin (No. 454) is not to be considered as a complete treatise on coal sampling, but rather as a contribution to the growing list of studies on the principles governing the establishment of specifications for the sampling of coal.

An attempt is made to give a rigorous treatment of the theory of random sampling. The mathematical development has been extended to cover orderly sampling so that the effect on accuracy of picking increments in an orderly way can be compared with actual random sampling.

Copies of this 127-page bulletin may be obtained at 20 cents each from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Heating, Ventilating and Air Conditioning Guide—1944

American Society of Heating and Ventilating Engineers

The 22nd edition of the Guide issued by the American Society of Heating and Ventilating Engineers contains 49 chapters of technical data and general information pertaining to all phases of heating, cooling, ventilating and air conditioning, and related phases of refrigeration. The chapters are grouped in 7 sections entitled—Principles; Heating and Cooling Load Calculations; Combustion and Consumption of Fuels; Steam and Hot Water Heating; Air Heating, Cooling and Conditioning; Automatic Controls, Instruments and Motors; Special Applications and Miscellaneous.

The new volume includes 846 pages of technical data; 288 pages of equipment data; and the Roll of Membership of the Society. A large Volume Diagram and a Mollier Diagram for Moist Air is also furnished. Bound in stiff blue covers, size 6 × 9. Price $5.00.

The Oxy-Acetylene Handbook

The Linde Air Products Company

This comprehensive and authoritative textbook on basic oxy-acetylene welding and cutting procedures has been planned primarily for use in schools and colleges, but it is equally serviceable as a shop manual and reference work.

The book is in 7 Parts covering General Principles, Welding of Ferrous Alloys, Welding of Non-Ferrous Alloys, Miscellaneous Applications, Cutting, Inspection and Management, and two appendices dealing with Welding and Cutting Data, and The Air-Acetylene Flame and Its Uses. The text comprises 40 chapters which are admirably illustrated with 390 linecuts and halftones. The subject matter is limited to those operations and principles with which the student and the experienced operator are concerned.

The book contains about 600 pages, size 6 × 9¹/₄ and includes a 14-page index. Bound in stiff durable covers. Price $1.50.

Guide to Weldability of Steels

American Welding Society

Given a design and a welding process for fabricating it, this book presents the data necessary for a readily reproducible method by means of which the effect of welding procedure upon the ductility of the heated zone adjacent to the weld in plain carbon and low-alloy steels can be determined. Aside from the data given, only two tests are required—an end quench on the steel, and a notch-bend test of the steel.

The book, bound in flexible paper covers, comprises 90 pages, size 6 × 9 in. and includes many tables, charts and diagrams. Price $1.00.

MacQuown's Coal Directory and Buyers Guide

Edited by W. C. MacQuown

The 21st (1943) Edition of "MacQuown's Coal Directory and Buyers Guide" has just been published and the announcement received claims it to be "the last word in coal information." This volume comprises four parts—Part 1 dealing with Coal Selling Companies, Part 2 with Coal Operating Companies, Part 3 with Coke Plants and Part 4 with Anthracite, Coal Docks on the Great Lakes and B & O Coals.

The standard edition contains approximately 800 pages, size 9¹/₄ × 12 in., and is priced at $25.00. An abridged edition is also available at $15.00 per copy.

Principles and Practice of Flow Meter Engineering

By L. K. Spink

This handbook has just appeared in a new and enlarged edition, the sixth since the book was first published, in 1930. The book, 232 pages in length, is illustrated with photographs, diagrams and curves, and contains all the tables and formulas needed for any ordinary liquid or gas flow computation. In the Liquid Section, methods for determining compressibility factors of liquids at temperatures near the critical, a new and more accurate method of correlating temperature expansion data on petroleum oils, a quick method of correcting for tap locations and a short-cut method of correcting for viscosity are some of the features. Price $3.00.

1943 Wage and Hour Manual

With the issuance of the Economic Stabilization, Premium Pay, and Minimum Work-Week Orders, a new set of rules and regulations has been pyramided upon the controls previously established under the Wage and Hour Law. A comprehensive guide to these controls is provided by the 1943 edition of the Wage and Hour Manual. More than 1000 rulings and interpretations relating to wages, salaries and hours of work are included in this volume and correlated with others in the new Manual and in the 1942 edition.

Following the general style of earlier editions the 1943 Manual is arranged in four parts. Part I includes all changes made since March 1942 in controls under the Fair Labor Standards Act. Parts II and III contain similar material under the Public Contracts Act and a group of miscellaneous Federal statutes relating to wages and hours. Part IV contains the text of all statutory and regulatory material and also analytical articles on wage and salary stabilization, premium pay regulation and the minimum wartime work-week. Parts I, II and III thus serve as a supplement to the 1942 Manual, and Part IV as a special guide to the controls fathered by wartime conditions.

The Manual contains 700 pages and is followed by a 32-page topical index (printed on colored stock) to all of the rulings, regulations, articles and interpretations. Bound in stiff blue covers, size 6¹/₄ × 9¹/₄. Price $7.50

Questions and Answers for Marine Engineers—Boilers and Engines

Compiled by Captain H. C. Dinger, U.S.N. (Retired)

"Boilers and Engines" is an exceedingly helpful handbook for men in the engine room. It contains 21 informative chapters—11 devoted to boiler topics and 10 to engines. Anyone preparing for his license examination will profit considerably from the study of these 370 pages of informative text.

Bound in paper covers, size 5¹/₈ × 8¹/₈. Price $2.00.

N.D.H.A. Annual Meeting

The National District Heating Association will hold its Annual Meeting June 14 and 15 at the Hotel William Penn in Pittsburgh. As customary, the program will consist largely of various committee reports encompassing a number of special papers. Among these will be "Connecting New Load and Plans for Holding It" by H. L. Martin of Boston Edison Company; "Current and Post-War Programs of the Steam Utilities" by H. A. Weitzman of the Rochester Gas and Electric Corporation; "Sizing Economizers and Condensate Coolers" by W. A. Schulmeister of the American District Steam Company; "Correlation of Steam Use in Buildings" by A. R. Mumford of Combustion Engineering Company; "Studies on the Use of Amines in Control of Corrosion in Steam Heating Systems" by A. A. Berk of the U. S. Bureau of Mines; "Some Results of Corrosion Research Work at Carnegie Institute of Technology" by D. S. McKinney; "Moving Pictures of Fuel Beds" by Otto de Lorenzi of Combustion Engineering Company; and "Experience with Diaphragm-Operated Relief Valve" by G. T. Siebenthaler of the Dayton Power & Light Company.

The Steam Station Engineering Committee's report, scheduled for the afternoon of June 15, will cover "Corrosion in Steel Coal Bunkers," "Problems in the Use of Inferior Wartime Coals," "The Position of Fuel in Post-War Planning," "Removal of Cinders from the Upper Passes of Boilers" and "Personnel Problems Involved in the Employment of Women in Steam Heating Plants."

The Annual Dinner will be held on Wednesday evening, June 14.

Industrial Coal Purchase Regulations Revised

The Solid Fuels Administrator has announced a revision of the industrial bituminous coal distribution regulations to conform to the supplies expected to be available in the various eastern and midwestern coal producing areas in the near future. These revisions tighten limitations upon industrial coal purchases from the two southern Appalachian districts, where demand already far exceeds supply, and eases the controls governing the remainder of the eastern-mined bituminous coals to encourage purchases for stockpiling while the coal is available. Controls upon midwestern mined coals were recently modified with the same objective.

Provisions have been included in the revised regulations to encourage railroads and industrial consumers to purchase larger amounts of the lower grades of coal for current use and to store the better grades for use in the period when higher quality grades will be scarce.

1. All industrial consumers of coal produced in bituminous production districts Nos. 1, 2, 3, 4, 6 and 13 (comprising central and western Pennsylvania, Maryland, Northern West Virginia, Ohio, the West Virginia "Panhandle" and Alabama) are permitted to order and receive, on and after May 1, at least their current monthly consumption requirements, regardless of stocks on hand.

2. Any industrial consumer with less than 30 days' supply on hand, calculated on the basis of his estimated November 1944 requirements, may purchase coal (except from the two southern Appalachian districts), in addition to his current requirements, in amount equivalent to at least 20 per cent of his estimated November 1944 requirements to build up his stockpile to a 30 days' supply as of that time.

3. Because of their scarcity, the amount of coal from Districts 7 and 8 (southern West Virginia, eastern Kentucky and parts of Virginia and Tennessee) which consumers may purchase is reduced 5 to 10 per cent monthly. However, such consumers may, for their own protection, substitute alternative eastern and midwestern coals to meet their needs.

4. Industrial consumers of special-purpose coals are forbidden to order or receive between May 15, 1944, and May 15, 1945, more than their consumption requirements, less their inventory on May 1. However, no such consumer is required to maintain an inventory of less than 30 days' supply of these coals.

The revised regulations generally retain most of the other features of the bituminous coal stockpile program that has previously been in effect.

Brown Instrument Plan for Veterans

A plan to provide war veterans with employment opportunities, almost upon the heels of their discharge from military service, has been initiated by the Brown Instrument Company, Philadelphia. The Company is providing each of the draft boards within a 35-mile radius of its plant with a list, weekly, of the jobs available, the type of men required and what experience, if any, is needed for each task. Where the veterans are qualified by experience or education to receive additional knowledge in the servicing, operation and maintenance of industrial instruments, they are offered an opportunity to receive instruction at the Brown school.

Veterans released from military service for disability or other reasons, are required to visit their draft boards as soon after their discharge as possible, and each receives a 1-C card, proving his discharge status. It is for this reason that the Company decided it would contact the veteran at the most logical place, namely, the draft boards.

The only requirement which the veterans must meet to fill the positions other than their ability and knowledge of the work, is that they shall be sufficiently recovered, physically and mentally, from their disability to permit them to engage in work.

Personals

J. A. Krug has resigned from the office of Director of the Office of War Utilities and on April 24 reported for duty as a Lieutenant Commander in the Navy. It is understood his assignment will be that of a damage control officer. His successor is Edward Falck, who has been advanced from the position of Deputy Director.

Robert M. Gates, President of the A.S.M.E. and of The Air Preheater Corporation, was recently honored by Purdue University with the degree of Doctor of Engineering. Mr. Gates is an alumnus of Purdue, Class of 1907.

R. O. Muller has retired as Chief Engineer of The Terry Steam Turbine Company, because of ill health, and is succeeded by **Douglas S. Seelye,** who has been associated with that company for the past 24 years.

Wallace Johnson has been appointed General Sales Manager of the Joshua Hendy Iron Works, at Sunnyvale, Calif. He is a graduate of California Institute of Technology in mechanical engineering and has been associated with the Hendy organization since 1942.

John Avery has been made Manager of the Blower and Compressor Department of Allis-Chalmers Company, succeeding G. L. Kollberg, who has retired.

British Power Station Performance

Statistical tables dealing with the performance of British power generating stations were published yearly before the war by the Electricity Commissioners, but this procedure was suspended with the outbreak of hostilities. However, a paper entitled "Standards of Performance of Generating Plant, Based on Five Years Operating Data" was given before the Institution of Electrical Engineers on February 3 and subsequently reported in *Engineering*. The authors, Messrs. R. W. Biles and G. W. Maxfield, are both connected with the Central Electricity Board, and the paper dealt with loading conditions, outputs and outages of a group of 23 stations which, for obvious reasons, were not identified.

These were divided into three groups: (1) those operating at 150 to 275 psi and having an average age of 18 yr; (2) those ranging in pressure from 300 to 600 psi with an average age of 12 yr; and (3) those in the 300 to 600 psi class with an average age of 3 yr. The total installed capacity of these stations increased from 553,500 kw to 778,500 kw during the 5-yr period but the average available capacity increased only from 425,500 kw to 537,800 kw. The average plant load factor for all the stations increased from 56 to 77 per cent. This failure of available capacity to respond to the installation of additional capacity led to an investigation of the cause.

This was found to have resulted largely from an increase in outages which, on the boiler side, were due to poorer quality of coal; for in the last three years the coal ran higher in ash and in the proportion of fines, owing to lack of grading at the collieries. Carbon in the ash from some of the stoker-fired boilers ran as high as 40 per cent. Boiler difficulties were responsible for over 67 per cent of the outages, the turbine room for 26 per cent, and auxiliary equipment for the remainder. In the case of the higher pressure stations the average thermal efficiency dropped from 22.5 per cent in 1939 to 21 per cent in 1942. While much of this falling off in efficiency was attributable to inferior coal, the use of older equipment was also a contributing factor, especially in the lower pressure group.

As two-thirds of the outages were due to boilers, the relative performance of those operating at different pressures and in the different age groups is of importance. With the low-pressure plants averaging 18 yr there were 2.06 breakdowns per boiler during the 5-yr period; with the 300- to 600-psi plants there were 1.84 outages per boiler in the 12-yr group and 3.5 in the 3-yr group. The fact that the most modern group had the worst record in this respect is attributed to initial operation troubles.

The low-pressure stations had an availability of 71.8 per cent when operating at 47.4 per cent load factor; the intermediate group, with an average age of 12 yr, had 71.5 per cent availability at 84.7 per cent load factor; and the new higher pressure stations an availability of 79.9 at 88.7 per cent load factor.

From the Interior of China

Some readers may recall the articles in COMBUSTION several years ago by Y. C. Lu, a Chinese engineer who had received his technical education at Cornell University and who at the time was associated with the Shanghai Power Company. He now is with the National Resources Commission in Chungking, China. The Editor recently received a letter from Mr. Lu in acknowledgment of some information that had been supplied him and it is thought that readers may be interested in the following excerpts from the letter relating his experiences following the seizure of Shanghai by the Japanese:

> "My escape from Shanghai was quite dangerous but is sensational when I think of it now. I managed to report myself and family as refugees and in disguise we sailed from Shanghai by a small steamboat to a fishing port, from which we crowded into a native sailboat. We sailed along the southeastern seacoast and arrived at Foochow in eighteen days. In pre-war time no boat was considered safe along the coast except steamers which ordinarily would only take 36 hr to cover the same voyage. As the wind was not favorable, the boat arrived five days behind schedule. During the last few days, we had only a few pieces of sweet potatoes and a glass of water for daily food and drink. After we arrived, I had to carry my two children (one was 5 years old, the other 3 years) to go on shore; they were too weak to walk for lack of food.
>
> "Foochow is the last seaport remaining in our hands, though at present it is blockaded by the Japanese. Leaving my family there, I proceeded to Chungking. My present work is in charge of the technical section of the Electricity Department. As the Department controls practically all important enterprises throughout Free China, I am fully occupied by my present work. We have a general plan for rehabilitating power plants in the occupied districts and for building future power supply. When the time is ripe for its publication and when I can find time to write I will try to write something along that line for the readers of your magazine."

Smoke Prevention Association to Meet June 6–9 at Detroit

The following program has been announced for the 38th Annual Meeting of the Smoke Prevention Association of America which will be held at Detroit on June 6 to 9, inclusive, with headquarters at the Hotel Statler:

Tuesday, June 6 (Luncheon Meeting)

"Fuel Conservation Program," R. R. Sayers, Director, U. S. Bureau of Mines.

"Smoke Abatement and City Planning," George F. Emery.

"Conservation after Combustion," R. E. Thomas.

"Influence on Post-War Smoke Abatement Work of the Bituminous Coal Research Program," Julian E. Tobey.

"Service Training of the Operating Personnel, as It Affects Fuel Conservation and Smoke Abatement," Hugh P. Dolan.

"City Incineration," Robert H. Stellwagon.

Wednesday, June 7 (Morning Session)

"New Developments of Front Overfeed Stokers," Thatcher W. Rea, Detroit Stoker Co.

"Smoke Abatement from the Stoker Manufacturer's Viewpoint," J. W. Armour, Riley Stoker Corp.

"Fly Ash Collection at the Boiler," J. A. Hoffman, Hoffman Combustion Engineering Co.

"Studies of Stoker Fuel Beds (Illustrated)," Otto de Lorenzi, Combustion Engineering Company.

Wednesday, June 7 (Afternoon Session)

"Some of the Economies Effected by Fly Ash Collection," Leonard F. Lang, Western Precipitation Corp.

"Studies of Boiler Fly Ash Collection," A. P. Darlington, American Blower Corp.

"Innovations in Incineration and Fly Ash Collection," Ellis E. Smander, Detroit Incinerator Corp.

"Methods of Control of Stack Emission from Powdered Fuel-Fired Equipment," Valory S. Baretta, Detroit Edison Company.

Thursday, June 8 (Morning Session)

Round Table Discussion on Railroad Locomotive Smoke Abatement and Fuel Problems.

Thursday, June 8 (Evening Session)

Joint Fuel Conservation Meeting at Rackham Memorial Building.

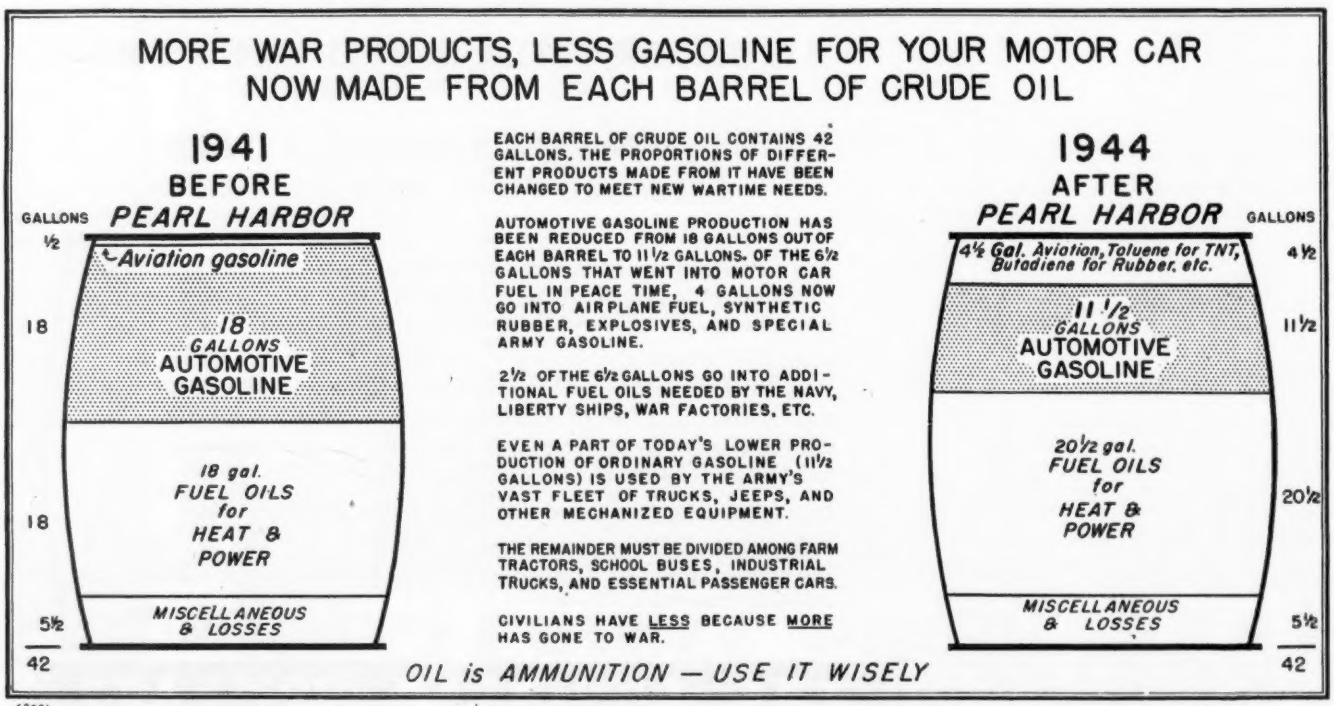
"Fuel Efficiency Program," Thomas C. Cheasley, Fuel Supervisor, U. S. Bureau of Mines.

Friday, June 9 (Morning Session)

"Weather and Air Pollution," Clarence J. Root, Detroit Weather Bureau.

"Power Practices in Detroit Water Works," A. C. Michael.

"A Résumé of the History of Atmospheric Solids Collection in the City of Detroit." Frank J. Gibbons, Chief Smoke Inspector, Detroit.



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1941 figures are for the entire year; 1944 figures are for the month of January.

Prepared by Petroleum Administration for War.
Division of Research

The above shows at a glance the present breakdown of a barrel of crude oil as compared with the pre-war period

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Boiler Water Columns

The Reliance Gauge Column Company has just published Catalog 415 describing boiler water columns with and without alarms for pressures above 250 lb per sq in. This 22-page publication is completely illustrated with halftones and linecuts and also includes water gage equipment.

Combustion Control

Leeds & Northrup Company has just issued a new 16-page catalog (N-01P-163) entitled "L & N Combustion Control, Type P." The bulletin describes the application of this system to different types of boilers and fired with different types of fuel—coal, pulverized coal, gas and oil. The bulletin shows how the system regulates fuel feed and draft by a simple electrical balance, varying the settings of valves, dampers or vanes in definite proportion to steam demand. At the same time, furnace pressure is automatically regulated. This combustion control system is designed for the smaller industrial or municipal power plant.

Continuous Blow-Off Systems

The Cochrane Corporation has just issued a 12-page publication (4081) which describes and illustrates the application of continuous blow-off systems. The bulletin explains the heat saving that can be accomplished, the advantages from the standpoint of regulating boiler concentrations, the type of equipment available for different heat balance requirements, and gives diagrams and halftones of installations, heat exchangers, etc.

Conservation of Fuel

This 24-page booklet "Conservation of Fuel For War" is a reproduction of the Bureau of Mines' Information Circular 7263, "Industrial Insulation with Mineral Products" by Oliver Bowles, Chief, Nonmetal Economics Division. It is printed by the Industrial Mineral Wool Institute as a contribution to the government's fuel conservation program.

A full description of loose, granulated, blanket, block, board and pipe covering types of mineral wool insulation is given with examples of equipment and places where each product may be used to obtain best results.

A free copy of the booklet will be supplied upon request, if made on company letterhead stationery, to the Industrial Mineral Wool Institute, 441 Lexington Avenue, New York 17, N. Y.

Condensate-Purity Instruments

Leeds & Northrup Company have just issued a revised 24-page catalog (N-95-163) covering its line of Micromax condensate-purity recording instruments for the steam plant. This bulletin describes how condensate is sampled continuously by means of a conductivity cell, and its purity indicated and recorded automatically by a Micromax instrument. Flash signal or sound alarms may be used with the apparatus, or (if so equipped) the Micromax instrument can control a valve and automatically divert contaminated condensate to waste. A simple L & N signalling conductivity controller is also listed for the first time.

Combustion Control

The Engineer Company has issued a 12-page bulletin (B. D. 44) describing the Enco combustion-control equipment, particularly suited to the needs of the smaller industrial boiler house with a limited operating force. Various types of regulators are shown and hook-up diagrams given covering balanced draft, furnace pressure and steam-pressure regulation. Enco stoker control as applied to either steam or motor-driven stokers is also covered.

Compressors and Vacuum Pumps

Ingersoll-Rand Company announce a new 32-page catalog of compressors and vacuum pumps in sizes from $^1/_2$ to 10 hp. This bulletin covers the Type "30" line of air-cooled machines; also a 3-stage dual-pressure portable and two 3-stage high-pressure units. The high-pressure units are 3- and 4-cylinder machines producing discharge pressures of 2000 lb and 3000 lb and are designed for special industrial uses requiring such pressures for intermittent operation.

Degasification of Water

Cochrane Corp. has issued an 18-page bulletin (No. 4076) which admirably illustrates and describes a number of equipments that are available for the removal of gases from water at various temperatures. The topics discussed include the removal of oxygen and carbon dioxide from water without the use of steam, the removal of small quantities of ammonia, the removal of hydrogen sulphide and carbon dioxide simultaneously. Different designs of Cochrane deaerators available for the elimination of gases in connection with boiler plants are also given.

Feed Water Regulation

The 6th Edition of "Mechanical Feed Water Regulation for Boilers" by Professor E. P. Culver has been published by the Northern Equipment Company. This 32-page booklet contains numerous illustrations, diagrams and chart reproductions. It covers the principles of boiler feed water control, and describes mechanical equipment available to meet various operating conditions. Differential pressure control and feed pump control are also discussed.

Pneumatic Ash-Handling Systems

The Beaumont Birch Company has issued a new 30-page catalog describing its "Vac-Veyor" system for the automatic removal by suction of ashes, fly ash and soot. Each page is devoted to fully dimensioned diagrams of separate parts, covering two sizes (6- and 8-in.) and two types of the system—i.e., for delivering ashes either dry or damp.

S-A Boilers

An interesting 28-page booklet on the S-A type boiler has been issued by Foster Wheeler Corporation, containing numerous illustrations and giving operating data at a number of well-known plants. Method of operation and ability to fire two or three different fuels simultaneously are described. Numerous photographs showing close-up details of construction are also given. The bulletin includes a a large and simplified chart giving the heat content of steam.

Skip Hoists

The C. O. Bartlett & Snow Company has just released a 4-page bulletin (No. 92) featuring the Company's new Plug Feed Type Skip Hoist Loading Gate. The folder is complete with detailed diagrams and a table giving the dimensions of eleven standard sizes.

Valve Reseating Equipment

The Leavitt Machine Company has just published a 32-page catalog (No. 40) featuring its line of Dexter valve reseating machines. Different types of equipment for reseating gate valves, globe valves and pump valves are admirably illustrated and described in this attractive bulletin.

Water Analyses

National Aluminate Corporation has issued a reprint of the paper "The Interpretation of Analyses and Problems Encountered in Water Deposits," by Messrs. J. A. Holmes and A. O. Walker, from the Proceedings of the A.S.T.M. This 7-page paper is an attempt to describe the problems encountered when investigating a scale sample, and to describe some of the methods used to identify the components in the scale.

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